***Astronomy* tests 10 giant binoculars** PAGE 92

**What makes galaxy groups hang together?** PAGE 46

**Spot minor planet Vesta from your backyard** PAGE 78

April 2003

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## Eye on the distant universe

### Behind the domes at Hawaii's Mauna Kea

CHASING THE SUN

## Aussie eclipse in photos

PAGE 80

ACCESSORY REVIEW

## Rock-solid Paramount from Software Bisque

HISTORY OF ASTRONOMY

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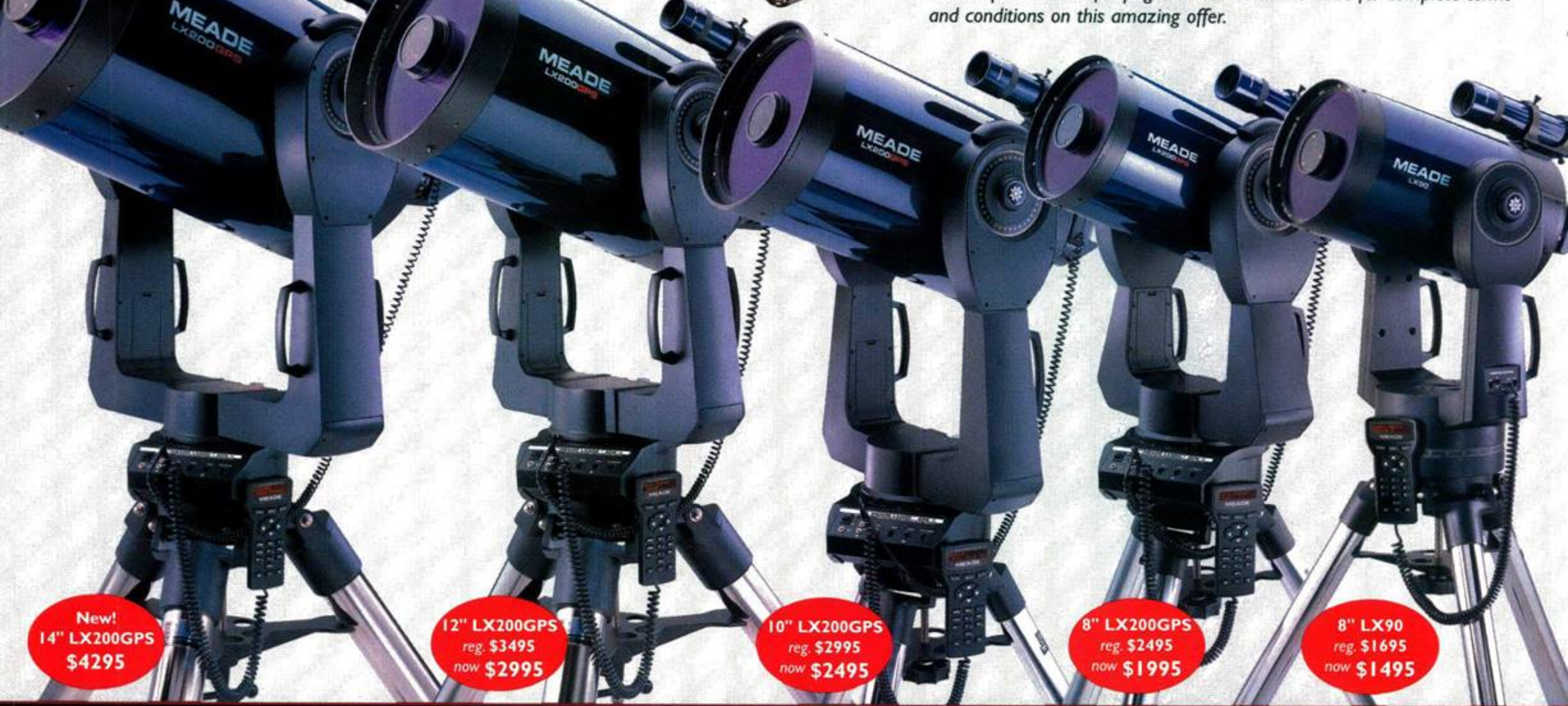
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DPM Library

# A Comparison of GPS Schmidt-Cassegrain Telescopes

| | Meade 8", 10", 12", 14" LX200GPS | Competing 8" and 11" GPS |
|---|---|---|
| **Primary Mirror Lock** | Yes; standard equipment. Cancels residual mirror shift during visual, photographic, or CCD imaging applications | No |
| **Zero Image-Shift Microfocuser** | Yes; standard equipment. Operates from Autostar II handbox and permits 4-speed microfocusing, while maintaining precise image centration during CCD imaging | No; must be purchased separately from an alternate supplier at a cost of approx. $200 to $300 |
| **Download of Software Revisions** | Yes; the latest software version, as well as custom and updated guided tours, comet and asteroid positions, may be downloaded in minutes, and at no charge, from the Meade website | No; software and data stored in the hand controller are not updatable without returning the hand controller to the factory; motor control software upgrade or debugging requires complete replacement of the electronic circuit board in the fork arm assembly |
| **Software Download, Automatic GO TO, and Automatic Tracking of Earth Satellites** | Yes; current earth satellite orbital data (including International Space Station, Space Shuttle, etc.) may be downloaded; telescope then automatically acquires and tracks satellite at correct tracking rate | No |
| **True-Level Tripod Sensor** | Yes; automatically compensates to a precision of 10-arcminutes for user error in leveling tripod during GPS alignment | No; absence of true-level sensor requires user to precisely level the tripod **manually**. Mis-leveling of the tripod by user results in alignment star errors of up to 5° or more during GPS alignment |
| **Maximum Slew Speed** | 8° per second | 3° per second |
| **Time Required to Perform a 120° Slew** | 15 seconds | 40 seconds |
| **Drive Speeds, each axis** | 185 speeds, from 0.01x sidereal to 8° per second | 9 speeds, from 0.5x sidereal to 3° per second |
| **Tracking Rates** | sidereal, lunar, or custom-selected from 2000 rates | sidereal, lunar, or solar |
| **Celestial Object Database** | 147,541 objects | 40,000 objects |
| **High-Precision Pointing Mode** | Yes; permits GO TO pointing precision within 1-arcminute | No |
| **Flash Memory** | 3.5-Meg | 1.0-Meg |
| **Permanent Periodic Error Correction** | Yes, both axes | One axis only; second axis unprogrammable |
| **Encoder Resolution** | 0.14 arcsecs | 0.26 arcsecs |
| **Internal Battery Compartments for cordless powering** | Yes; user-supplied C-cell batteries located inside the fork arms negate any need for external power cords. (If desired, telescopes may alternately be powered by external cord.) | No |
| **Multi-Coated Correcting Plate** | Included with optional UHTC; increases light transmission by about 2% and reduces internal tube reflections | Not included and not available as an option |
| **Enhanced Optical Coatings** | Optional UHTC group results in light transmission **greater than 85%** at **all** wavelengths between 450nm - 700nm and transmission of **90% to 94%** at wavelengths between 540nm - 690nm, a range which includes the important Hα line at 656nm | Competing 11" coatings have a **peak** transmission of 85% at 510nm; **light transmission at all other visual wavelengths, including the Hα line, is below 85%** |
| **Hand-Matched Optics** | Yes; since their inception in 1980 all Meade Schmidt-Cassegrain optics have been individually hand-matched. Individual match-figuring is performed on the large correcting plate, resulting in a smooth optical figure | Yes; individual matching is performed on the small secondary mirror |
| **Primary Mirrors** | Oversize diameters (8.25" on 8" LX200GPS; 10.38" on 10" LX200GPS; 12.38" on 12" LX200GPS) result in increased edge-of-field illumination | Mirror diameters (8" telescope includes 8.1" mirror; 11" includes 11.1" mirror) result in lower edge-of-field illumination |
| **GPS Antenna** | Omnidirectional, located squarely on top of fork arm; GPS signals are receivable through a larger sky-area | Omnidirectional, but location at approx. 45° angle inside fork arm results in approx. 45° sky-area being inaccessible to GPS signals |
| **Field Tripods** | 8" and 10" tripods include 2"-dia. chromed steel legs; 12" and 14" tripods include 3"-dia. chromed steel legs; all tripods include a **cast aluminum** leg-lock spreader bar | 8" and 11" tripods include 2"-dia. painted steel legs and a **plastic** leg-lock spreader bar |
| **Polar Axis Bearings** | 1 x 4" dia. ball bearing and 1 x 2.25" dia. ball bearing mounted coaxially to the polar axis. Both bearings contribute to radial and axial stiffness | 1 x 1.88" dia. roller bearing mounted coaxial to the polar axis and 3 x 0.88" dia. ball bearings rolling on an unshielded aluminum track. Only the 1.88" bearing contributes to radial stiffness |
| **Swing-through of optical tube in fork arms** | Yes; telescope can observe 100% of sky area | Yes; telescope can observe 100% of sky area |
| **FCC (U.S.A.) and CE (Europe) certified for low electromagnetic interference** | Each telescope carries a label confirming FCC and CE certifications | Telescopes do not carry any labels confirming domestic or foreign certifications |

Comparisons are based on current Meade LX200GPS models and on competitive telescopes and user manuals received in 11/2002.

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**Astronomy** · VOL. 31 · NO. 4

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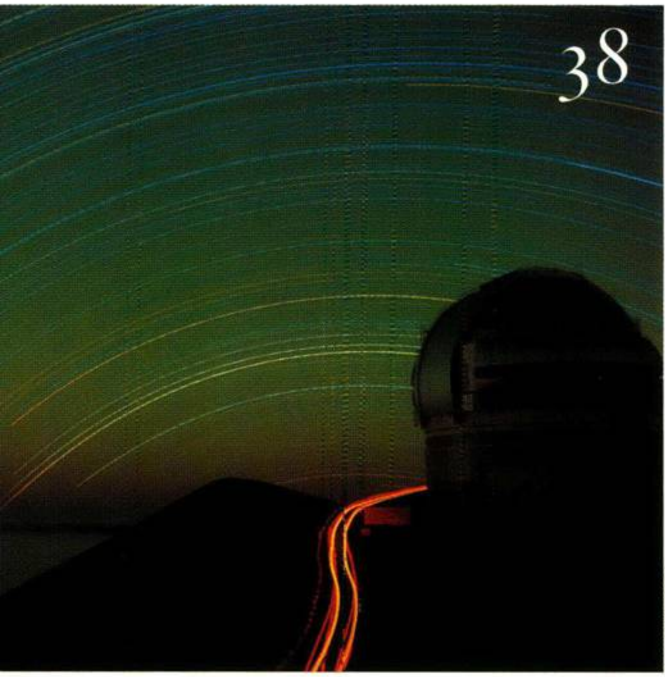
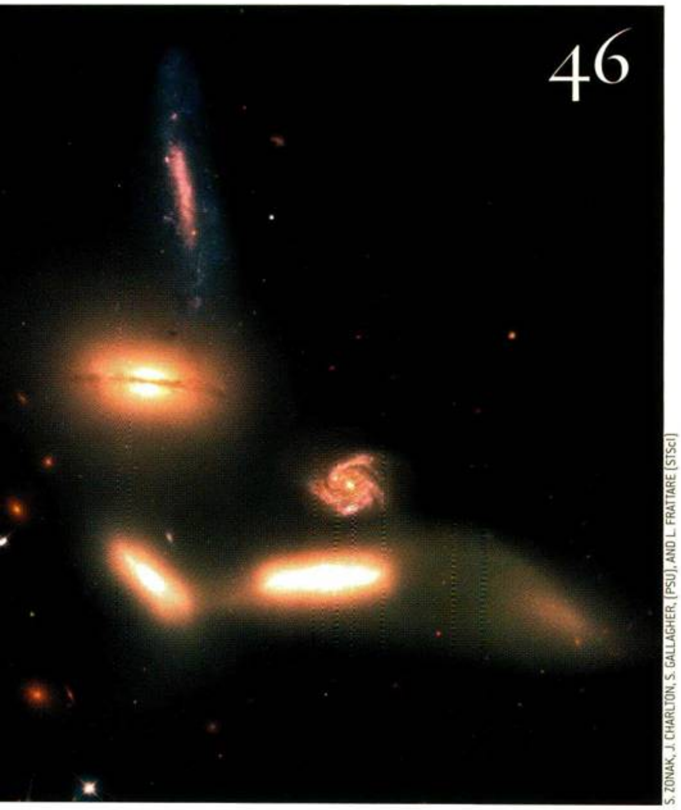

38

RICHARD WAINSCOAT


46

S. ZONAK, J. CHARLTON, S. GALLAGHER, (PSU), AND L. FRATTARE (STScI)

# features

COVER STORY
## 38 Big eye on the universe

The finest telescopes on Earth sit atop Mauna Kea, the highest peak in Hawaii. Take a virtual tour up the mountain to get a behind-the-scenes look at the observatories. BOB BERMAN

EXTRAGALACTIC ASTRONOMY
## 46 The turbulent world of compact galaxy groups

Like desert oases, compact galaxy groups spring up in barren voids. Find out what these fast-moving, tight-knit systems reveal about the nature and evolution of cosmic structure. MARCIA BARTUSIAK

COSMOLOGY
## 52 Searching for the golden ratio

Weaving itself through geometry, relativity, botany, and astronomy, the golden ratio *phi* is one of those special numbers that gives shape to our universe. MARIO LIVIO

CELESTIAL PORTRAITS
## 74 Centaurus and Antlia

The large constellation Centaurus the Centaur holds an abundance of celestial treats from the galaxy and beyond. The smaller Antlia the Air Pump is somewhat star-starved but contains some extragalactic appetizers. TOM POLAKIS

PLANETARY OBSERVING
## 78 Spot a naked-eye asteroid

While the asteroid Vesta normally remains dim, this month it is a naked-eye object — if you know where to look. With these tips, it's a challenge any backyard observer can meet. RICHARD TALCOTT

ECLIPSE CHASING
## 80 Darkness Down Under

Tens of thousands of observers flew halfway around the world last December to catch half a minute of totality. RICHARD TALCOTT

TECHNIQUES
## 86 All-in-one filter system

Sirius Optics' VFS-1.25 provides color highlights in a single unit rather than numerous filters required for observing sessions. PHIL HARRINGTON

EQUIPMENT REVIEW
## 88 The Paramount GT-1100 ME

No more tangled cables. The new Paramount GT-1100 ME offers observers elegance in design, accuracy in automation, and an extended arsenal of cable pass-thrus as well as a new cable conduit. GREGORY TERRANCE

EQUIPMENT ROUNDUP
## 92 Two eyes on the sky

Two eyes are always better than one, especially when they are partnered with giant binoculars. In this review of several giants, we help you find the binoculars that best fit your needs and your budget. PHIL HARRINGTON

JUAN CARLOS CASADO AND ISABEL GRABOLEDA

## departments

06 **This month in *Astronomy***
Chasing the shadow Down Under

12 **Beautiful universe**
Seeing double in Perseus

14 **Letters**

16 **Interview**
Alan Stern

18 **Bob Berman's strange universe**
Aquarian equinox

20 **Glenn Chaple's observing basics**
Learn how to find and observe Mercury, which emerges from the solar glare as an evening planet this month.

22 **News**
- The other Lord of the Rings: Uranus
- Looking earthward
- The Orbital Space Plane
- Neutrino mass
- X rays from young stars

60 **The sky this month**
Mercury leads the spring lineup of planets.
MARTIN RATCLIFFE AND ALISTER LING

72 **Ask Astro**
Galactic travel, Galileo's telescopes, and gravity and light

100 **New products**
- Takahashi TOA-130
- Swarovski ATS 80 spotting scope
- Pro-Optic 1¼″ eyepieces
- *Moon Mission* game

104 **Book reviews**
*Space Odyssey*
*Where Is Everybody?*
*Tycho & Kepler*

111 **Resources**

112 **Coming events**

113 **Advertiser index**

114 **Reader gallery**
Leonid meteor shower

Astronomy
Eye on the distant universe

**ON THE COVER**
The world's most powerful telescopes cluster on the summit of Mauna Kea, Hawaii, forming a research facility that is a gateway to the universe. One of thousands of important images made on Mauna Kea is this shot of the Trifid Nebula (M20). It was created with the 3.6-meter Canada-France-Hawaii telescope. Jean-Charles Cuillandre used the CFH12K camera for the composite exposure. CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE /COELUM

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**MAUNA KEA CONTROVERSY:** What's all the fuss?

**HICKSON COMPACT GROUPS:** Galaxy mergers in action

**HICKSON COMPACT GROUPS:** A pictorial exhibit

**OBSERVING VESTA:** Expanded finder table and map

**AUSTRALIAN ECLIPSE:** More reader photos

**Astronomy.com**

BY DAVID J. EICHER

# Chasing the shadow Down Under

Last December 4, totality washed over two separate landscapes as the Moon's shadow darkened southern Africa at the start of its path and southern Australia at its conclusion. *Astronomy* was pleased to partner with Specialty Tours of Clearwater, Florida, to create an eclipse expedition to the land Down Under. Senior editor Rich Talcott, a 16-year veteran of the magazine's staff and experienced eclipse chaser — as well as coauthor of the celebrated book *Chasing the Shadow* — led our tour group. Despite the doubts posed by intermittent clouds, our group of nearly 40 saw totality grace Ceduna, on the shores of Murat Bay.

Rich's exciting story of the expedition and the eclipse, "Darkness Down Under," starts on page 80. Not only did Rich, his wife, Evelyn, and their fellow travelers meet new friends (see photo at right), but they also received a tremendous tour of Australian cities and countryside. The expedition began with a "pretour" on November 23, 2002, with a trip to Cairns on Australia's northeastern coast, and a subsequent trek to explore the Great Barrier Reef by scuba and snorkel.

Sydney Observatory, built in 1858, welcomed our group for an astronomical jaunt. In Melbourne, the Swinburne Centre for Astrophysics and Supercomputing marked the first objective. Astronomers from the facility opened its doors to our group. Members of the Astronomical Society of Victoria guided *Astronomy's* travelers through the Old Melbourne Observatory.

Rich next ably led the group to Adelaide en route to Ceduna for eclipse day. The clouds separated shortly before totality to enable Rich and his companions to capture the event with eye and on film — an unforgettable sight in an unforgettable place.

At the end of this month, from April 26–May 4, I will be in Hawaii to lead a tour through the islands' astronomical hot spots, culminating with a behind-the-scenes tour of the major observatories on the summit of Mauna Kea. See this month's story by Bob Berman, "Big Eye on the Universe" (page 38), for an in-depth status report on science taking place at the largest observatories on the mountain, as well as current controversies surrounding it.

**SENIOR EDITOR** Rich Talcott and friend in Australia. EVELYN TALCOTT

*Astronomy* will be gearing up its presence with not only special trips this year, but also a slew of star parties and science meetings. We hope to see you there.

Yours truly,

**DAVID J. EICHER**
*Editor*

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VoL. 31 No. 4

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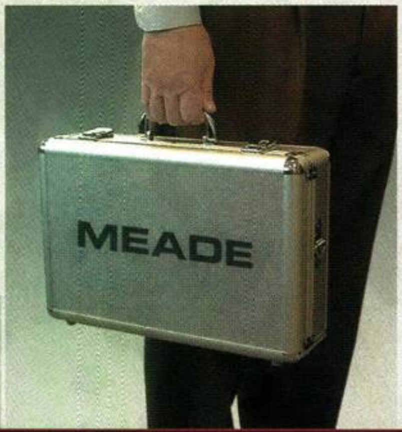

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| **LX90, LX200GPS models:** | 8" LX90; 7", 8", 10", 12", 14", 16" LX200GPS |

## HOW TO ORDER

**1.** Buy any qualifying Meade telescope from an authorized Meade dealer in the U.S.A. between August 15, 2002 and April 30, 2003.

**2.** Fax or mail a copy of your dealer's invoice, plus the completed warranty card packed with the telescope, along with your payment of $99 to Meade Instruments/Attn: Customer Service, and request the "$99 Eyepiece Offer." *Requests must include your complete shipping address and phone number.*

**3.** We will ship your eyepiece package to you within 30 days of our receipt of your request. Meade Instruments will pay for all shipping and insurance charges; safe arrival is guaranteed.

**Other terms and conditions:** Payment may be made by personal check (payable to Meade Instruments) or credit card (VISA or MasterCard). **California residents must add $7.67 sales tax, for a total payment of $106.67.** Requests for this special offer must be postmarked not later than May 31, 2003. This special offer is valid only for new Meade telescopes ordered and received within the U.S.A. (Outside the U.S.A. contact your Meade international distributor.) There is no limit to the quantity of telescopes each person may order: each qualifying telescope is eligible to receive the special eyepiece package. Prices shown are suggested U.S. mail-order retail prices. **The SP26mm eyepiece (shown in photos above) is packed with each qualifying telescope as standard equipment.

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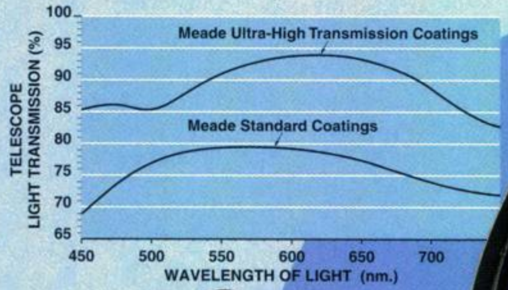

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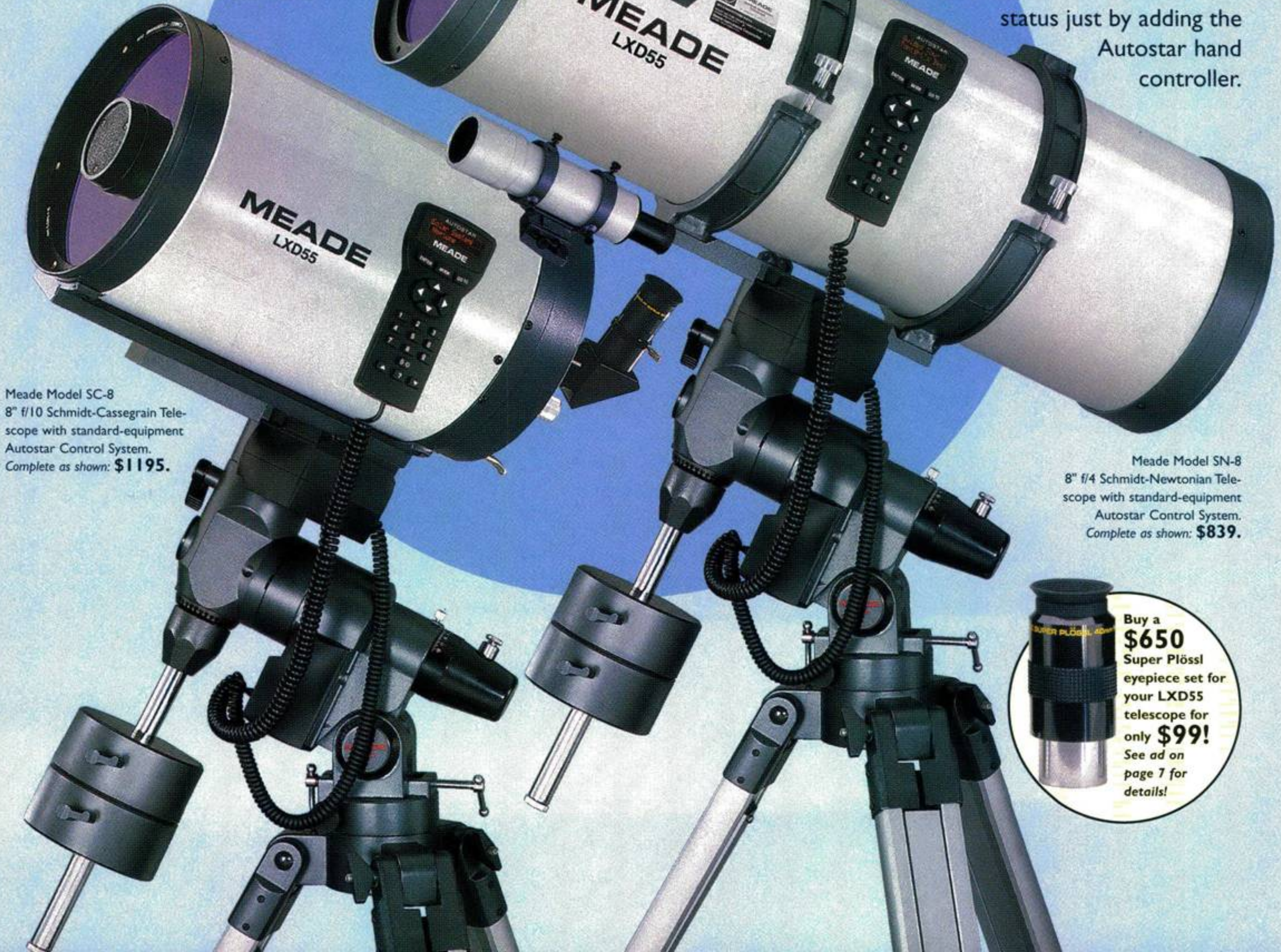


Meade Model SC-8
8" f/10 Schmidt-Cassegrain Telescope with standard-equipment Autostar Control System.
*Complete as shown:* **$1195.**

Meade Model SN-8
8" f/4 Schmidt-Newtonian Telescope with standard-equipment Autostar Control System.
*Complete as shown:* **$839.**

**Buy a $650 Super Plössl eyepiece set for your LXD55 telescope for only $99!** ***See ad on page 7 for details!***

## 6", 8", and 10" LXD55-Series Schmidt-Newtonians with Autostar

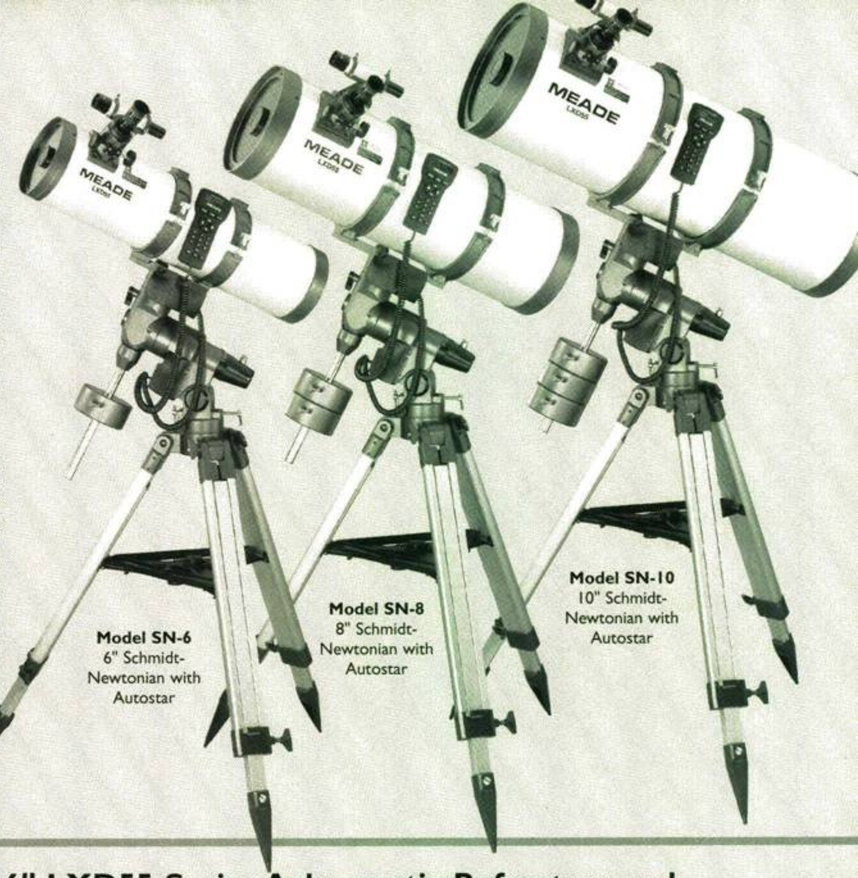
Meade American-made diffraction-limited Schmidt-Newtonian optics yield pinpoint stellar images over extremely wide fields, with *one-half* the coma of paraboloids of the same focal ratios. Fast f/4 (8", 10") or f/5 (6") optics present brilliant, rich-field imaging of nebulae, galaxies, and star clusters. High-power lunar and planetary images reveal subtle detail often lost in telescopes of lesser resolution. The standard-equipment **Autostar Dual-Axis Control System** permits an amazing range of operations: *automatic GO TO capability* at 4.5°/second to 30,223 database objects (galaxies; diffuse and planetary nebulae; star clusters; the complete Messier, Caldwell, IC, and NGC catalogs; double and variable stars; eight major planets; asteroids; and comets); *nine selectable slew and slow-motion speeds* from 1x sidereal to 4.5°/sec.; plus *automatic sidereal-rate tracking* in RA, and much more.

**SPECIFICATIONS: Models SN-6, SN-8, and SN-10 Schmidt-Newtonian Telescopes** — Each complete telescope includes 6" f/5, 8" f/4, or 10" f/4 Schmidt-Newtonian optical tube assembly with $MgF_2$ coatings on the correcting lens and standard aluminum coatings on the primary and secondary mirrors (Ultra-High Transmission Coatings available optionally); white-enameled metal optical tube with machined-aluminum mirror cell; quick-release cradle ring assembly with locks; 6 x 30mm achromatic viewfinder; metal rack-and-pinion focuser with eyepiece holders for both 1.25" and 2" eyepieces; Series 4000 Super Plössl 26mm eyepiece. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12v DC auto cigarette lighter plug or from 115v AC home outlet); operating instructions.

| | |
|---|---|
| **6" Model SN-6 Schmidt-Newtonian** | **$695** |
| **8" Model SN-8 Schmidt-Newtonian** | **839** |
| **10" Model SN-10 Schmidt-Newtonian** | **995** |

**Ultra-High Transmission Coatings (UHTC) group:** 6" Model SN-6 – $85; 8" Model SN-8 – $125; 10" Model SN-10 – $150.

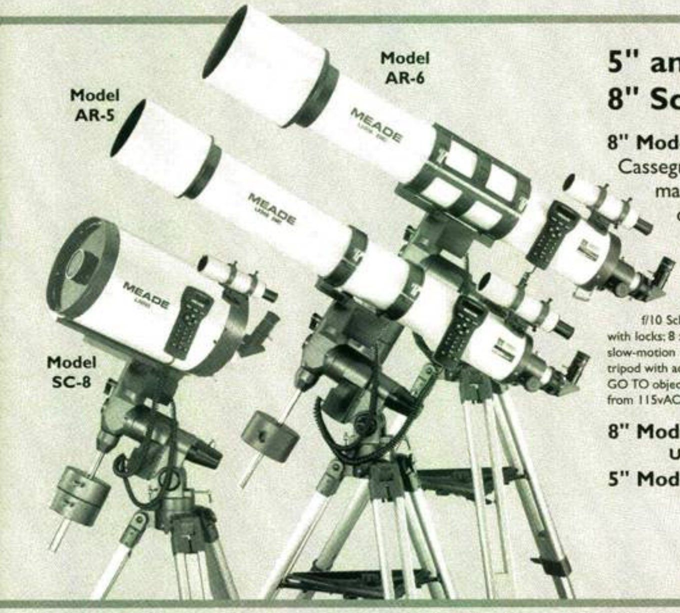
**Packing & shipping charges** in the 48 states: 6" – $75; 8" – $85; 10" – $95.



**Model SN-6**
6" Schmidt-Newtonian with Autostar

**Model SN-8**
8" Schmidt-Newtonian with Autostar

**Model SN-10**
10" Schmidt-Newtonian with Autostar



**Model AR-5**

**Model AR-6**

**Model SC-8**

## 5" and 6" LXD55-Series Achromatic Refractors and 8" Schmidt-Cassegrain with Autostar

**8" Model SC-8:** Includes the f/10 optical system of the Meade 8" LX200GPS for razor-sharp Schmidt-Cassegrain photo-visual imaging of the Moon, planets, and deep-space. All the telescope required by many amateurs for a lifetime of serious observing. **5" Model AR-5, 6" Model AR-6:** Excellent optical performance from the classical 2-element achromat design, with images rich in resolution and contrast and a minimum of chromatic aberration. Models SC-8, AR-5, and AR-6 allow for the full range of Autostar functions described above.

**SPECIFICATIONS: Models SC-8 Schmidt-Cassegrain and AR-5 and AR-6 Achromatic Refractors** — Each complete telescope includes 8" f/10 Schmidt-Cassegrain with $MgF_2$/standard coatings or 5" f/9 or 6" f/8 achromatic refractor with EMC super multi-coatings; quick-attach cradle ring assembly with locks; 8 x 50mm viewfinder; Series 4000 Super Plössl 26mm eyepiece; diagonal prism. LXD55 German-type equatorial mount with worm gear drives and electric slow-motion controls on both axes; micrometric controls for azimuth and elevation adjustments; illuminated polar alignment finder with reticle; variable-height field tripod with accessory shelf. Autostar dual-axis control system with digital readout display; 9-speed drive controls; 30,223-object celestial software library and automatic GO TO object-locating. Battery pack accepting eight (user-supplied) D-cells (optional 25 ft. cords permit powering from either 12vDC auto cigarette lighter plug or from 115vAC home outlet); operating instructions.

| | |
|---|---|
| **8" Model SC-8 Schmidt-Cassegrain** | **$1195** |
| **6" Model AR-6 Achromatic Refractor** | **895** |
| **5" Model AR-5 Achromatic Refractor** | **695** |

**UHTC group** for Model SC-8 — $175

**Packing & shipping charges** in the 48 states: 8" – $85; 5" – $85; 6" – $95.

## 6" and 8" LXD55-Series Schmidt-Newtonians and 5" Achromatic Refractor with Electronic Controller

All the performance and features of the Autostar models above, but with 4-speed (2x, 8x, 32x, 4.5°/sec.) dual-axis Electronic Controller in place of Autostar. Upgrade to the Autostar Controller, available separately, at any time.

**SPECIFICATIONS: Models SN-6EC, SN-8EC, and AR-5EC** — Identical in every detail to the respective Models SN-6, SN-8, and AR-5, above, but with Electronic Controller (EC) in place of Autostar Hand Controller. Electronic Controller includes four dual-axis slewing speeds: 2x for photoguiding; 8x for image centering in the main telescope; 32x for image centering in the viewfinder; 4.5°/second for rapid-slew of the telescope across the sky; plus automatic sidereal-rate RA tracking. ***#497 Autostar Controller may be added at any time in the future and permits the full range of Autostar functions, including automatic GO TO, as described for Autostar-equipped telescopes, above.***

| | |
|---|---|
| **6" Model SN-6EC Schmidt-Newtonian** | **$579** |
| **8" Model SN-8EC Schmidt-Newtonian** | **699** |
| **5" Model AR-5EC Achromatic Refractor** | **579** |
| **#497 Autostar Controller,** for any EC-model above | **149** |

**Ultra-High Transmission Coatings (UHTC) group:** 6" Model SN-6EC – $85; 8" Model SN-8EC – $125.

**Packing & shipping charges** in the 48 states: 6" SN-6EC – $75; 8" SN-8EC – $85; 5" AR-5EC – $85. All prices shown in this ad are suggested U.S. national mail-order retail prices.

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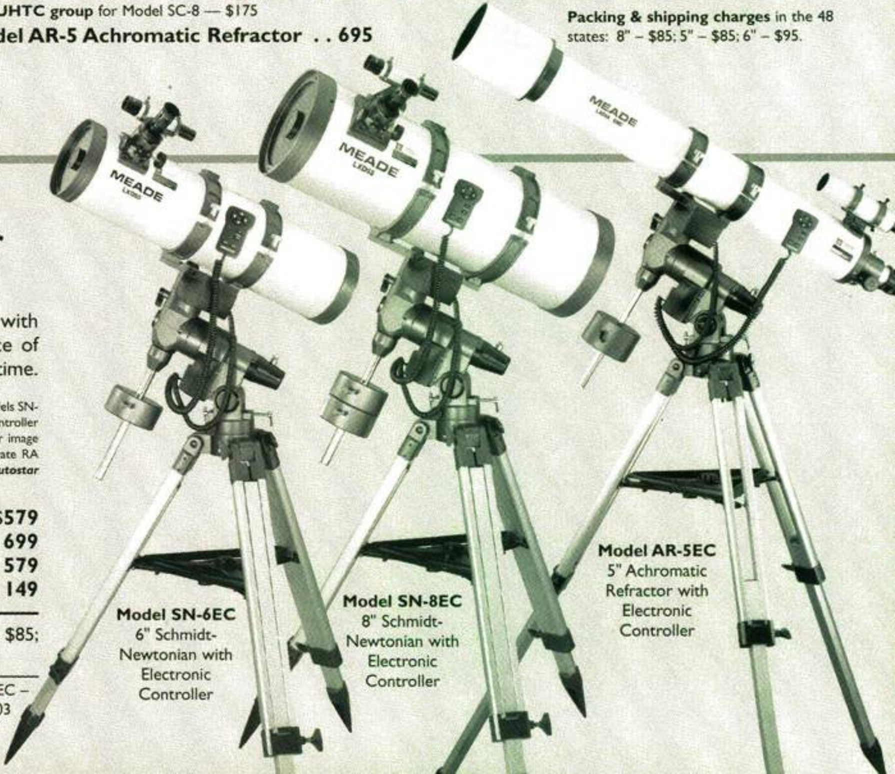


**Model SN-6EC**
6" Schmidt-Newtonian with Electronic Controller

**Model SN-8EC**
8" Schmidt-Newtonian with Electronic Controller

**Model AR-5EC**
5" Achromatic Refractor with Electronic Controller

# MEADE®

# RESEARCH-GRADE ACCESSORIES

## Series 4000™ Super Plössls
### 52° field; multi-coated

Meade 4-element Super Plössls, updated and redesigned to utilize the latest in optical glass-types, are the finest general-purpose eyepieces available. For observing hairfine lunar and planetary detail, splitting close doubles, or studying tenuous nebulosity in deep-space, Meade SP's deliver unmatched contrast and image sharpness. Rubber eyeguards fold down for eyeglass wearers–a feature not available on competing brands. Multi-coated. All focal lengths through 32mm are parfocal.

**Super Plössls** (SP: 4-elements; 1.25"; 52°):

| | |
|---|---|
| **6.4, 9.7, 12.4, 15, 20, 26mm** | each: **$79.95** (4.54) |
| **32mm** (52°); **40mm** (44°) | each: **99.95** (5.26) |
| **56mm** (52°; 2") | **199.95** (7.02) |

## Series 4000™ Ultra Wide Angle
### 84° field; multi-coated

The ultimate eyepieces: extreme image sharpness over an amazing 84° field. A perfect optical match with Schmidt-Cassegrains and fast Newtonians.

**Ultra Wide Angle** (UWA; 8-elements; 1.25"; 84°)– **4.7mm: $169.95** (5.26); **6.7mm: 199.95** (5.26); **8.8mm** (1.25"/2"): **239.95** (7.02); **14mm** (1.25"/2"): **299.95** (7.02)

## Series 4000™ f/6.3 Focal Reducer/ Field Flattener

Manufactured to exclusive Meade optical designs; threads on to any Meade or Celestron Schmidt-Cassegrain rear cell and converts f/10 scopes to f/6.3 (or f/6.3 SCT's to f/4), while significantly flattening the field. Use with SCT visual or photo accessories. Actual visual field is increased by 56%, for fine wide-field views of star fields and nebulae. In astrophotography, reduces exposure times by about 50%, while producing an actual field diameter of 1.5" at the film plane. A tremendous aid with CCD imagers in reducing image size for locating and centering images on CCD chips. 4-element optics; multi-coated; 41mm clear aperture.

**$129.95** (5.26)

## 2x Telenegative Barlow (1.25")

**#122:** Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25"

**$47.95** (4.54)

## 2x Short-Focus Barlow (1.25")

**#126:** Only 2.5" long, the #126 works well with any telescope accepting 1.25" eyepieces, even those with limited focus range. Maintains the high image quality of the #122, above. Insert the #126 into star diagonal for 2x or insert star diagonal into #126 for 3x. 26mm clear aperture. Multi-coated.

**$47.95** (4.54)

## 2x-3x Variable Barlow (1.25")

**#127:** Precision internal sliding lens assembly permits continuously variable power settings between 2x and 3x. Engraved scale indicates power in use. Yields bright, sharp, high-contrast images on telescopes of all types. Multi-coated; 1.25".

**$59.95** (4.54)

## New! 2" Diagonal Mirrors with UHTC

**#929:** Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes UHTC-coated (95%+ reflectivity) precision optical flat made at the Meade factory; with 1.25" eyepiece adapter. **#930:** Same as #929 but with 2" barrel to fit into focusers with 2" eyepiece-holders.

**#929** or **#930,** each: **$119.95** (6.85)

## 45° Erecting Prisms

Fully coated roof prisms to invert the astronomical image in Schmidt-Cassegrains or refractors during terrestrial observations, while presenting a convenient 45° observing angle. Specify **#927** (.965"), **#928** (1.25"), or **#931** (fits .965" focuser, accepts 1.25" eyepieces).

**$42.95** (3.86)

## World's Most Advanced Illuminated Reticle Eyepiece

**Series 4000 Plössl 9mm,** with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Multi-coated optics. **Internal batteries included.** Bullseye reticle. 1.25".

**$149.95** (6.14)

**Series 4000 Plössl 9mm**—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator.

**$129.95** (5.26)

**Series 4000 Photo-Visual Color Filters** (1.25")–Premium filters, made of purest crown optical glass, dyed in the mass. For increased contrast and resolution on the Moon and planets. Thread into the barrels of virtually all 1.25" eyepieces sold today. Fully coated.

**#8 Lt. Yellow; #11 Yellow Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue**

each **$14.95** (2.73)

| | |
|---|---|
| **Set #1**–4 filters: #12, #23A, #58, #80A | **49.95** (4.54) |
| **Set #2**–4 filters: #11, #25A, #47, #82A | **49.95** (4.54) |
| **Set #3**–4 filters: #8, #21, #38A, #56 | **49.95** (4.54) |

**Series 4000 Moon Filter (#ND96):** Reduces glare and irradiation during lunar observing. 13% uniform light transmission across the visual spectrum. Threads into 1.25" barrels.

**$16.95** (2.73)

## #905 Variable Polarizer (1.25")

For glare reduction in observing the Moon. Includes two Polarizer filters mounted in a machined cell and permits continuously variable light transmission from 5% to 25%, to compensate for varying lunar surface brightness according to the Moon's phase and the aperture of the telescope. Accepts 1.25" eyepieces.

**$49.95** (5.26)

## Electric Focusers for SCT's

For extremely smooth microfocusing of the image. Does not affect use of the manual coarse-focus knob.

**#1206 Electric Focuser:** Plugs into control panel of Meade 8", 10", 12" LX200 models and operates from LX200 hand controller. (Not for LX200GPS models.)

**$149.95** (7.48)

**#1205 Electric Focuser:** For **all** other Meade 8", 10", 12" SCT models; includes separate hand controller; accepts one self-contained (user-supplied) 9v. battery.

**$169.95** (7.88)

## #777 Off-Axis Guider for SCT's

Internal prism diverts light for monitoring telescopic image during long-exposure astrophotography. Threads to any Meade or Celestron rear cell. Use with illuminated reticle eyepiece and T-Mount for your 35mm camera.

**$79.95** (6.85)

## Series 4000™ 2x Apochromatic Barlow Lens

**#140:** The most advanced Barlow lens available for commercial telescopes, the Meade #140 includes 3-element, multi-coated, air-spaced optics. Doubles the power of any eyepiece with which it is used and yields images absolutely unmatched in resolution, contrast and color correction. The #140 optically complements any telescope — refractor, reflector, or Schmidt-Cassegrain. Accepts 1.25" eyepieces. Mechanical components are of machined aluminum and brass. Lens diameter is 28mm; clear aperture 26mm.

**$79.95** (5.26)

## Series 4000™ Super Wide Angle
### 67° field; multi-coated

For exquisite wide-angle images at low-to-medium powers, with pinpoint edge-of-field resolution. Ideal for star fields, galaxies, and other deep-space phenomena. SWA 13.8mm, 18mm, and 24.5mm are superb complements to the #140 Barlow, above.

**Super Wide Angle** (SWA; 6-elements; 1.25"; 67°)–**13.8mm: $139.95** (4.54); **18mm: 149.95** (4.54); **24.5mm: 179.95** (5.26); **32mm** (2"): **239.95** (7.02); **40mm** (2"): **299.95** (7.02)

## Series 3000™ Plössls
### 50° field; multi-coated

Meade Series 3000 Plössls yield the finest image corrections obtainable from the classical 4-element Plössl design. Focal lengths from 5mm through 25mm are parfocal, so that, at most, only slight refocusing of the image is necessary from eyepiece to eyepiece. Unlike competing moderately-priced Plössls, Meade Series 3000's are **multi-coated** for maximum light transmission and image contrast. Chrome-plated brass barrels are threaded for standard filters. All eyepieces are fitted with fold-down rubber eyecups for comfortable observing. The PL40mm *(far right in photo)*, an excellent complement to any ocular set, produces spectacular low-power, wide fields, ideal for scanning the Milky Way. Manufactured exclusively to Meade optical designs, Series 3000 Plössls yield fine, high-resolution results on reflectors, refractors, and Schmidt-Cassegrains of any focal ratio.

**Series 3000 Plössls** (4-elements; 1.25"; 50°)

**5, 6.7, 9.5, 16, 25mm** each: **$49.95** (3.86); **40mm $79.95** (3.86)

#911B
#911N
#908B
#908N

**Series 4000 Nebular Filters**—Premium multi-layer interference filters, the finest obtainable. Use broadband ("B") filters to block most forms of light pollution; use narrowband ("N") filters in heavily light-polluted areas or for extremely high-contrast observing of faint nebulae.

| | |
|---|---|
| **#908B**–Threads into 1.25" eyepieces, 26mm dia. | **79.95** (4.54) |
| **#911B**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **99.95** (5.26) |
| **#908N**–Threads into 1.25" eyepieces, 26mm dia. | **89.95** (4.54) |
| **#911N**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **119.95** (5.26) |

**Series 4000 Oxygen-III Filters**
Observe diffuse emission and planetary nebulae as you never thought possible! Exclusive Meade 60-layer interference coating technology isolates the 496nm and 501nm O-III lines to tremendously enhance observable nebular structural detail in all telescopes.

| | |
|---|---|
| **#908X**–Threads into 1.25" eyepieces, 26mm dia. | **99.95** (4.54) |
| **#911X**–Threads on to rear cell of Schmidt-Cassegrain telescopes. 36mm dia. | **149.95** (5.26) |

## Vibration Isolation Pads

Designed by Meade engineers, these isolation pads reduce typical telescope-tripod vibration damping times *to less than one second.* A tremendous aid for both visual and photographic astronomy. Place one pad under each tripod leg. #895 Vibration Isolation Pads, per set of three:

**$49.95** (6.85)

## MA12mm Illuminated Reticle Eyepiece

Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle; rubber eyecup. Wireless red LED illuminator and variable brightness control. 1.25". **Batteries included.**

**$99.95** (3.45)

As above but with 6 ft. cord and plug for Meade telescopes with power panels, in place of wireless illuminator.

**$79.95** (5.26)

## Camera Adapters

Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-mount, available separately.

**.965": $27.95; 1.25": $29.95** (3.86)

## Variable Tele-Extender

For eyepiece-projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Sliding cell with lock permits wide range of projection magnifications with the same eyepiece. Use with T-mount for your camera.

**$39.95** (3.86)

## Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-mount for your camera.

**$39.95** (3.86)

## T-Adapters for SCT's

Rigidly couples camera to telescope for prime focus photography with any Meade or Celestron Schmidt-Cassegrain. Use with T-Mount for your 35mm camera.

**$26.95** (3.86)

## CCD-Photo-Visual Flip-Mirror Systems

An essential accessory for imaging with any brand of CCD imager or for astrophotography with a 35mm camera. Flip mirror "down" to center the image while viewing with an eyepiece at 90°; flip mirror "up" to pass light on to CCD chip or 35mm camera film plane. Each unit includes: precision optical-flat Pyrex® mirror; 2-axis mirror-adjustment screws and locks for precise image centering; extra-fine helicoid focusing of the eyepiece; extension tubes for attaching either 35mm camera (using T-Mount) or CCD imager (using either T-threads or 1.25" barrel). Threads to rear cells of all Schmidt-Cassegrain telescopes; may remain on telescope and used in place of diagonal prism for visual observing as well.

*"Over the past 10 years I have used all manner of flip-mirrors. The Meade Flip-Mirror Systems are absolutely the best—rock solid, high-precision, beautifully manufactured; they virtually eliminate all flexture between the CCD and telescope."* — Jack Newton

**#644 Flip-Mirror System:** Accepts any 1.25" eyepiece. Mirror clear aperture: 22mm. Use with CCD's up to Pictor 416XTE, ST-7, or AP1, or smaller; or visual observing with 1.25" eyepieces.
**$149.95** (7.02)

**#647 Flip-Mirror System:** Accepts either 1.25" or 2" eyepieces. Mirror clear aperture: 40mm. Recommended for full-field 35mm astrophotography or with CCD's of any size, including all Meade Pictor Series through 1616XTE, or ST-4 through ST-10; or AP2, AP7; or for visual applications with 1.25" or 2" eyepieces.
**249.95** (8.49)

**#157 1.25" Adapter:** Permits use of either Flip-Mirror on telescopes with 1.25" eyepiece-holders. (Requires approx. 2" additional focus travel with #644, 3" with #647.)
**15.00** (3.86)

#644

MEADE
FLIP-MIRROR SYSTEM

#647

ELECTRONIC CONTROLLER
MEADE

### #1209 Zero Image-Shift Microfocuser

Identical to the Microfocuser supplied with Meade LX200GPS telescopes, but provided with a separate hand-box for use with all other Meade SCT models (e.g., LX10, LX50, LX90, LX200) or for Schmidt-Cassegrains of other brands. Threads directly to the telescope's rear cell. Permits extremely precise focusing of the image during visual or photographic applications; during CCD applications maintains precise image centration on even the smallest CCD chips. Operates at four speeds, from extremely slow to fast; accepts both 2" and 1.25" eyepiece barrels. Requires 8 x AAA (user-supplied) batteries.

**$249.95** (9.85)

### Epoch 2000® Sky Software

**The most powerful astronomical software ever made available can now be yours for only $99!**

**Epoch 2000sk** *(upper display at left)*: Use the most advanced, most precise full-color sky software ever created, to zoom-in on telescopic fields **smaller than one arc second!** Dynamically reads out the R.A. and Dec. of the cursor position anywhere in the field **and updates R.A. and Dec. instantaneously as the cursor is moved about the field.** Meade LX200 owners can use Epoch 2000sk for remote auto-centering of objects in the telescopic field **to a precision of 30 arc seconds,** routinely! Print professional-quality star charts in either black-and-white or color, at any zoom setting or sky scale between 180° and one arc second, with your own customized borders, headers, footers, margins, fonts, colors, and grids.

**Epoch 2000ip Image Processing Software:** Enhance and analyze your CCD images with the same sophisticated techniques used by professional astronomers to uncover hidden structure in a spiral galaxy or obscure detail on the surface of a planet.

**EPOCH 2000sk Sky Software:** 19 million objects, including the complete Hubble Guide Star Catalog; supplied on CD-ROM for Windows 95, 98, 2000, NT, and XP ........ **$99**

**LX200 Interface Cable:** for Meade LX200/LX200GPS operation by Epoch 2000sk........ **25**

**EPOCH 2000ip Image Processing Software:** On CD-ROM for Windows 95, 98, 2000, NT, and XP.... **99**

f/3.3 CCD FOCAL REDUCER

### Series 4000™ f/3.3 CCD Focal Reducer/Field Flattener

Revolutionary 3-element Meade design permits ultrafast CCD imaging with **increased** edge-of-field resolution and color correction! Reduces CCD exposure times by up to 80%. Threads on to the rear cell of any Meade or Celestron Schmidt-Cassegrain. Converts f/10 Schmidt-Cassegrain telescopes to **f/3.3** and f/6.3 SCT's to **f/2.** Variable T-Adapter (included) allows range of f/ratios between f/3 and f/5 on f/10 SCT's and between f/1.9 and f/3.2 on f/6.3 SCT's. Use with CCD imagers of any brand and chip dimensions. Not for visual or photographic applications. Multi-coated; 41mm clear aperture.

**$149.95** (5.26)

### Plössl 25mm Illuminated Reticle CCD Framing Ocular

MEADE
PLÖSSL
CCD FRAMING

Displays rectangular frames of all popular CCD chip sizes, including all Meade Pictor models; ST-4 through ST-8; AP1, AP2; and others. Shows precisely the image size and orientation that appear on CCD chip. Insert directly into telescope eyepiece-holder, or use with Flip-Mirror *(above)*. Includes 4-element coated Plössl optics; lockable spacer ring to fix focus position; rubber eyecup; variable LED illumination control; batteries. 1.25".

**$129.95** (4.54)

### #825 8 x 25mm Right-Angle Viewfinder for ETX-90

Permits comfortable right-angle viewing. Replaces standard-equipment finder on 90mm ETX models, using the same bracket. Wide-angle, achromatic, coated optics; actual field 7.5°. Precise helicoid focusing.

**$49.95** (4.26)

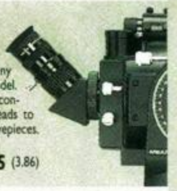
### #64 T-Adapter for ETX®

Threads to photo port of all ETX-90, ETX-105, and ETX-125 models. Rigidly couples any 35mm camera with removable lens to the telescope for lunar, planetary, or terrestrial photography. Includes extension tube for longer effective focal length, if desired. Use with T-Mount for your 35mm camera.

**$34.95** (3.86)

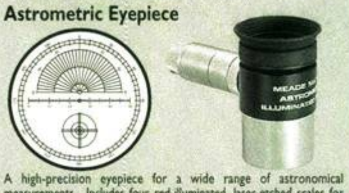
### #932 45° Erecting Prism for ETX®

For terrestrial observing with any ETX-90, ETX-105, or ETX-125 model. Yields correctly oriented image and convenient 45° observing angle. Threads to ETX rear cell. Accepts any 1.25" eyepieces. Coated roof prism optics.



**$49.95** (3.86)

### MA12mm Illuminated Reticle Astrometric Eyepiece



A high-precision eyepiece for a wide range of astronomical measurements. Includes four red-illuminated, laser-etched scales for measuring double star angular separations, position angles, planetary diameters, and lunar crater diameters, and for long-exposure photo-guiding. Modified Achromatic 3-element coated optics; diopter adjustment; rubber eyecup; variable LED illumination control; batteries. 1.25".

**$119.95** (4.26)

### Series 4000™ 8mm – 24mm Zoom Eyepiece

The finest zoom eyepiece available. High-resolution 7-element multi-coated optics, with 55° field at 8mm. Graduated scale in 1mm units indicates exact focal length in use. High-eyepoint yields comfortable observing even with eyeglasses. Internal zoom lenses move on the smoothest, most precisely-machined tracks yet developed for zoom optics. Performance is fully consistent with the finest fixed-focal length eyepieces. Threaded for filters; rubber eyecup; 1.25".

**$219.95** (6.38)

### ETX® Hard Carrying Cases

For secure storage or travel with your ETX. Thick-wall construction and die-cut foam lining. Accepts telescope, optional eyepieces, erecting prism, table tripod, hand controller, etc. Includes steel latches & key.

**#774** Case for ETX-90 models:
**99.95** (8.58)

**#776** Case for ETX-105EC:
**99.95** (8.58)

**#775** for ETX-125EC:
**149.95** (13.38)

### Dew Shields for ETX®

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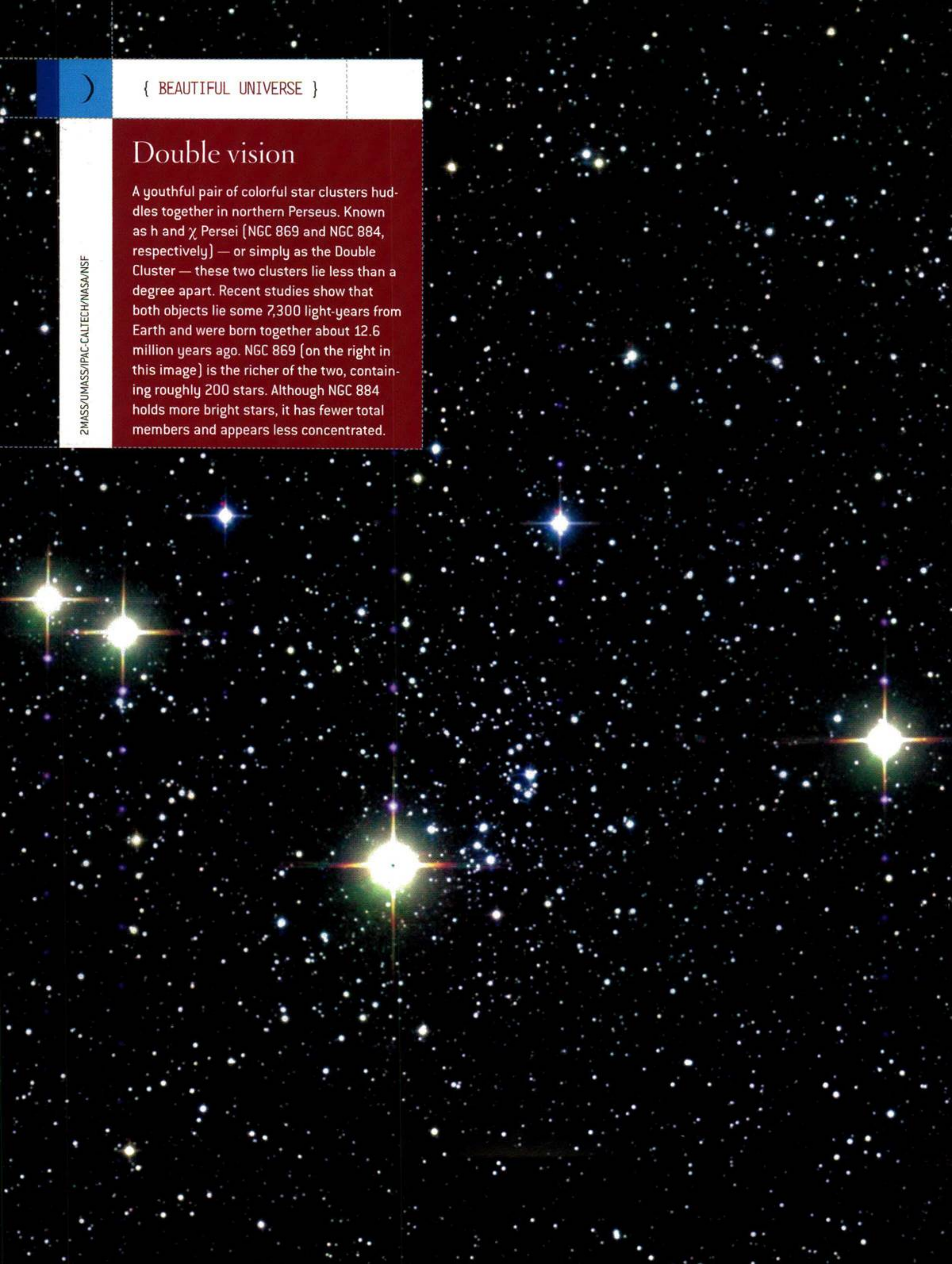
# Double vision

A youthful pair of colorful star clusters huddles together in northern Perseus. Known as h and χ Persei (NGC 869 and NGC 884, respectively) — or simply as the Double Cluster — these two clusters lie less than a degree apart. Recent studies show that both objects lie some 7,300 light-years from Earth and were born together about 12.6 million years ago. NGC 869 (on the right in this image) is the richer of the two, containing roughly 200 stars. Although NGC 884 holds more bright stars, it has fewer total members and appears less concentrated.



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# Night of shooting stars

After missing the 2001 Leonids due to clouds, I was not about to miss the 2002 show. I flew from Kansas to Rhode Island to try to catch the Leonids but flew back to Kansas when I did not like the weather patterns forming on the morning of November 18th. As I landed in Kansas, the skies were clearing. I observed the event at the Astronomical Society of Kansas City's observatory in Louisburg, Kansas, 20 minutes south of Kansas City, with more than 100 people.

The night began with a magnitude 0 earthgrazer that soared upward over the observatory dome at 11:30 P.M. This was the first earthgrazer I had ever seen, and three others graced the sky later that night.

Throughout the night, I recorded 81 meteors (although I missed quite a few while writing the information down). But during the peak, from about 3:30 A.M. until 4:30 A.M., we saw at least 113 meteors of all magnitudes. At 4:45 A.M., a Leonid of magnitude –2 left a two-second train. But by about 5:20 A.M. the meteor shower seemed to draw to a close.

While it might not have been a storm, it was quite a show. We saw many impressive meteors, and after the disappointment of the 2001 shower, we were very thankful for the clear weather. It was definitely a night to remember.

**ERIC FLESCHER**

ASTRONOMICAL SOCIETY OF KANSAS CITY,
KANSAS CITY, MISSOURI

**THIS BRIGHT LEONID METEOR** was caught on camera with a 17mm lens at f/3.5 and Fuji NPZ 800 film. ROBERT B. SLOBINS

## NexStar pointers

As an owner of a NexStar 11, I read Phil Harrington's review of the NexStar 8 GPS ("Going Global," January) with interest. I enjoy his articles and highly value his opinion. But I noticed a few discrepancies I would like to point out.

Harrington notes that the standard NexStar 8 features a database of 40,000 objects. Actually, the original NexStar 5 and 8 databases included about 18,000 objects. The computerized hand control for the new NexStar 5i and 8i scopes, replacements for the original models, is the same one used with the NexStar 8 and 11 GPS, and the database does contain more than 40,000 objects.

The article also stated that EQ North/South alignment is used to manually polar align the telescope, but these are the methods used after the scope is polar aligned on a wedge. This method even provides the option of automatically locating the required two alignment stars for you, providing the same convenience experienced when not using a wedge.

I would also like to share one feature of the NexStar 8 and 11 GPS and their smaller siblings, the 5i and 8i, that was not mentioned in the article — wedge alignment. This automates the polar alignment required when using a wedge — in other words, it accurately aligns the right ascension axis with Earth's axis. After the NexStar gets a fix on the sky, it points the telescope at the correct coordinates for Polaris (in the Northern Hemisphere) or Sigma Octanis (in the Southern Hemisphere) and prompts you to adjust the wedge to center the star in the eyepiece.

**MIKE SWANSON**

OKINAWA, JAPAN

*While the NexStar 8 GPS will offer some help when polar aligning the instrument on an equatorial wedge, the telescope will not do the entire procedure on its own (ahh, if only it would!). Instead, the telescope user must intervene to manually move the telescope toward the celestial pole once the wedge has been manually adjusted to match the observer's latitude and the tube has been automatically positioned parallel to the fork arms. The user must still move the tripod and wedge so that the fork arms (and tube) are pointed at the celestial pole.*

**PHIL HARRINGTON**

## Correction

In the February "Talking Back," Govert Schilling criticizes my November 2002 "Strange Universe" article about gravity. Schilling says that, contrary to what I'd written, Earth does not move in a geodesic, and the orbital motions of the planets have nothing to do with their motion in the bent space-time in the Sun's vicinity. He says that "only light rays follow geodesics." This is wrong on all counts, as can be confirmed by any textbook on relativity. Perhaps his confusion stems from mixing up normal geodesics with a particular variety called "null geodesics" that only light follows.

**BOB BERMAN**

*We welcome your comments. Send letters to Astronomy Letters, P.O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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BY WILLIAM SCHOMAKER

# Alan Stern

Late last year, both houses of Congress granted green-light approval for one of the most ambitious space exploration programs ever devised — to explore the frigid realms of the outer solar system beyond Pluto. And the captain of this cosmic cruiser, dubbed New Horizons, will be Alan Stern, planetary scientist and director of the Southwest Research Institute's Department of Space Studies, located in Boulder, Colorado. Stern specializes in the study of the origin and evolution of comets and larger icy bodies in the solar system, but he has also been the principal investigator on numerous NASA sounding rocket, Space Shuttle, and high-flying airborne astronomy missions.

**How will NASA's New Horizons endeavor alter our perceptions and understanding of the solar system and beyond?**

NASA's New Horizons mission to Pluto and the Kuiper Belt is going to revolutionize our understanding of the third major zone of the solar system — the Kuiper Belt, which of course lies beyond the inner, rocky planets and even the outer, giant planets. This is the largest and most populous zone of our planetary system, and it has never been reconnoitered. New Horizons will do just that, with flybys of the double planet Pluto-Charon as well as flybys of one to three Kuiper Belt Objects lying beyond Pluto. This will be the first mission since the Voyagers to visit unexplored planets. We expect to learn a great deal about the era of planet building, the workings of icy worlds, the history of cratering, the evolution of organic material in the solar system, and much more. Most exciting, however, we know from experience that by going to new places we will discover unexpected things, some probably even beyond our present-day imagination.

**ASTRONOMER ALAN STERN,** seated in a NASA research aircraft, enjoys pioneering new methods of capturing astronomical images. SWRI

**On a recent observing run, you jumped into the backseat of an F-18 fighter to chase the Sun. What was that all about?**

For more than five years now, we've been using high-performance NASA aircraft to pioneer a new kind of airborne astronomy. We've used a U-2 type aircraft to obtain infrared imaging of Comet Hale-Bopp; we've participated in NASA's 1998 Leonids airborne KC-135 observing campaign; we've chased and intercepted asteroid occultation events in F-18 Hornets; and now we are using image-intensified cameras aboard F-18s to determine if the putative Vulcanoid population of small asteroids inside Mercury's orbit really exists.

**How does one turn a war machine into an airborne observatory?**

Well, like a lot of the airborne work NASA does, I do my observing from an ejection seat, which makes for a different kind of observing run for sure. Actually, NASA's F-18s are test models based at the NASA Dryden Flight Research Center, on Edwards Air Force Base in California. To ready the aircraft for each observing mission, we and the Dryden engineers kit our astronomy gear, consisting of the imager, its control and power supply electronics, a real-time imaging display, an observing run checklist, and one very eager astronomer.

**What's the source of your affinity for the solar system? Why not study galaxies or supernovae?**

All of astronomy is interesting, there's no doubt. But what attracted me to planetary science, and what keeps me jazzed, are two things: the field's intimate connection to exploration, and the real testability factor that one achieves by comparing telescopically derived notions to the hard facts derived from instruments we can actually send to the places that we study.

**You are also a well-known author of two books and multiple essays. When and how did you get the writing bug?**

I guess I got that disease back in 1970 when my grandfather challenged me (seeing as how I said I was so interested in the subject) to write a book on planetary exploration. It was pretty bad, even for something an adolescent would write, but I liked writing a great deal and have endeavored to make it a part of my professional work. I hope that by now my writing has improved since that first foray in 1970. ■

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**RICHARD WOLFSON** (Ph.D., Dartmouth College) is Professor of Physics at Middlebury College in Vermont, where he has also held the George Adams Ellis Chair in the Liberal Arts. Decades of teaching at Middlebury, with its strong emphasis on the humanities, has made him an expert at demonstrating the logic and significance of physics to students from many fields. His writings have appeared in *Scientific American*, and he is the author of the textbook *Physics for Scientists and Engineers*, now in its 3rd edition.

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BY BOB BERMAN

# Aquarian equinox

Throughout time, in cultures spanning the globe, equinoxes were celebrated with fanfare. Some civilizations threw wild parties while more exuberant tropical cultures tossed in-laws from monuments. In our time, such rowdiness would disturb the neighbors: Our annual TV equinox announcement barely stirs the minds of Joe and Jessica Average. For most, this sole vestigial link with the heavens is greeted with apathy or misconception: "Hey, Jessica, they say eggs will balance today. Let's go to the 7–11 and buy some!" The media does its part by repeating such myths as, "Day and night are now equal." Surely, a few folks must glance at the newspaper's local sunrise and sunset listings and see that day is longer than night at every equinox.

Here is all you need to know about this yearly milestone, this famous link between human life and the sky.

If "March 21" pops to mind, you're dating yourself. For North Americans, the final equinox on that date happened in 1979. Reason: Equinoxes slowly migrate earlier and earlier as each century progresses. Before 1960 the spring equinox usually landed on the 21st. Nowadays it's exclusively on the 20th. Skipping the leap year at each century-change normally corrects this slide and re-sets the date to the 21st again. But a rare once-every-400-year calendar tweak befell 2000; that WAS a leap year, which let equinoxes keep slipping earlier, unchecked. Not to worry — it's all part of the straightforward 16th-century Gregorian calendar plan that only eleven people in the world understand.

At the moment of the equinox (exactly 8 P.M. EST), Earth is angled perfectly sideways to the Sun. The Sun then hovers directly over the equator, above the Colombian town of San Miguel de Guacamole. (Actually, I made that up.)

Both poles will be equally un-tipped toward that favorite star of ours and, as the media never tire of reminding us, days and nights should be equal.

But they're not. It would be true if our planet were like Mercury and had no atmosphere. But since thick horizon air bends the Sun's image upward by its own diameter, making it rise a few minutes earlier and set that much later than it would otherwise, the true date of equality is displaced by nearly a week.

March 20 is also aptly chosen to mark the start of spring and is a symbolic time of balance. From Penguinville to Irkutsk, the Sun rises and sets precisely due east and west. You can calibrate your sundial, that chore you've been putting off for so long. You can orient yourself and figure out which windows of your house face where. (The term "orient yourself" originally arose because if you knew which way the Orient lay, you could correctly point east. It's true, scout's honor.)

Here's a little-known goody that even most astronomers seem unaware of: Only on the equinox does the Sun move in a perfectly straight line across the sky. A time exposure any other day reveals the Sun on a curving path that's concave toward the north during the warm half of the year, and toward the south during the cold months. But on March 20 the solar track is laser-straight.

Can you figure out why? Typical readers of, say, *Popular Shotgun*, might not know, but as an advantaged *Astronomy* reader you already realize that northerly or southerly stars like Capella or Antares arc in sharply curving paths. Conversely, stars on the celestial equator (like those of Orion's Belt) march arrow-straight across the heavens. Well, on March 20 the Sun sits on the celestial equator and thus follows the rule, "when in Rome . . ."

It would be nice if Sun and stars could be seen together at the equinox. (A dark equinoctial total eclipse might do the job, and we'll get one in 2015. Deterrent: It's at the North Pole.) Then the Sun would visibly appear in front of a constellation that, since ancient times, has held special significance. Astronomers use that spot where the Sun hovers at the equinox as the zero point for celestial longitude.

Trouble is, that point is slipping among the constellations. The 25,780-year precessional wobble in our axis is the culprit. Its details would induce intense boredom or even hallucinations, but suffice to say the point the Sun occupies at the equinox creeps westward among the stars. Two millennia ago it was in the constellation Aries, and the equinoctial spot is sometimes still called "the first point of Aries." In the year 69 B.C., however, it moved into Pisces, where it's been ever since.

You probably want to know when the vernal equinox begins in the constellation Aquarius, to commence the Age of Aquarius, that golden time when supermarkets will again stock tasty tomatoes.

Don't hold your breath. At the present rate of precessional advance (50.2787 seconds of arc annually) the spring equinox will start to occur in Aquarius in the year 2597. We have another 600 years before the true age of harmony and understanding, when telephone solicitors will stop calling on weekends.

The equinox is indeed a milestone of nature, when earth and sky are almost poetically united in an ephemeral moment of symmetry and balance. Worth celebrating. Maybe an omelet. ■

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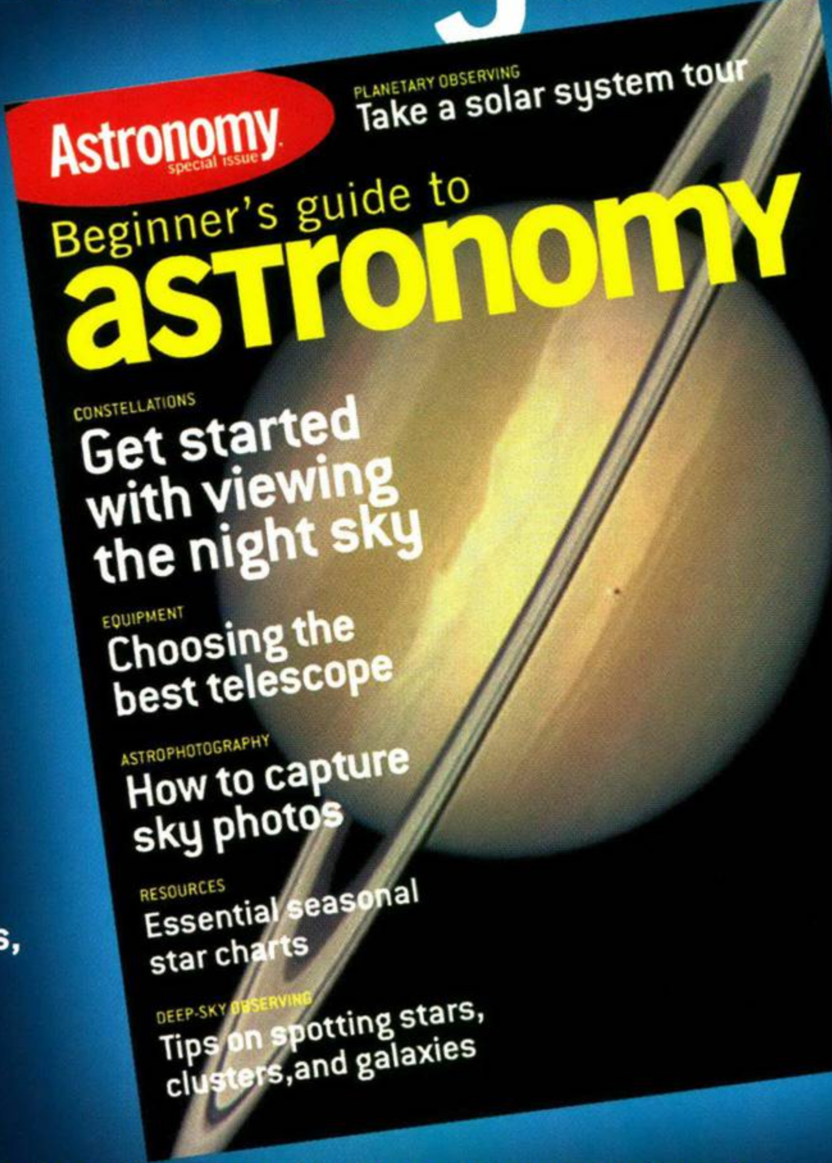
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BY GLENN CHAPLE

# Mercurial sightings

Legend has it that the great Polish astronomer Nicolaus Copernicus never saw the planet Mercury. The story is easy to believe. Perpetually close to the Sun, Mercury rarely strays from its glare. When it does (an event called an "elongation"), Mercury flirts with the horizon as an evening or morning planet. During a favorable elongation, which typically lasts a few weeks, Mercury is fairly easy to see — if you know when and where to look.

My first sighting of Mercury, some three decades ago, ranks as one of my biggest astronomical thrills. Early attempts to see the elusive little planet failed until one late March evening when I decided to give Mercury another shot. The Moon was supposed to lead me to my target, but because it was only an ultra-thin crescent, ferreting Moon and planet out of a rose-hued western sky with the naked eye was impossible. In desperation, I scanned the area with my telescope's finder. I recorded what ensued in a logbook that night.

"March 27, 1971, 7 to 8 P.M. EST. For the first time in my life, I saw the planet Mercury. It was shining in the evening sky a few degrees south of the one-day-old Moon. As it was, I had never seen the Moon at this early a stage, and the two in the same field in my finder scope were a beautiful sight. Mercury appeared as a reddish star, and in the telescope it looked like a tiny crescent, almost at 'half Moon' phase. Tonight was a memorable occasion, and my first sight of Mercury will not easily be forgotten."

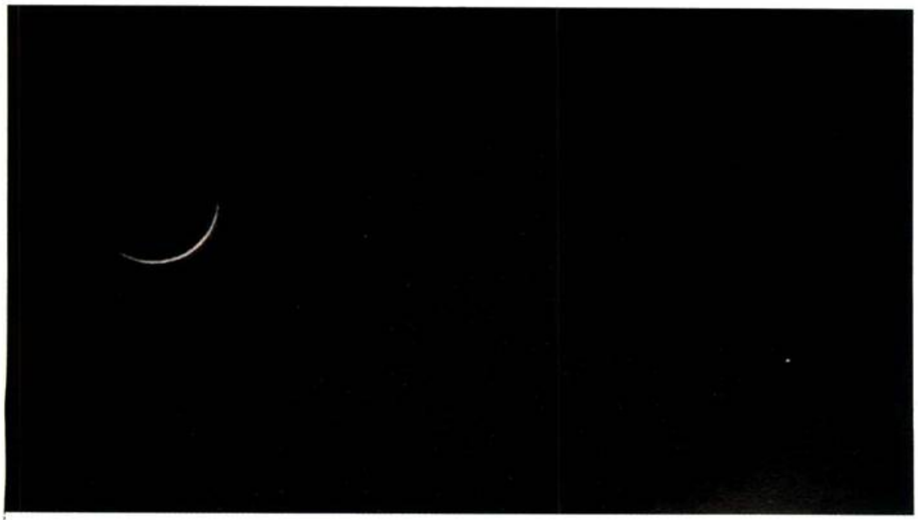
Now it's your turn to make a milestone observation. During most of April, we'll have an excellent chance to see Mercury in the early evening sky. Choose a spot with a clear view of the western horizon. On April 2, Mercury will be paired with a day-old crescent Moon — a mere sliver. About a half-hour after sunset, search the area just above the horizon (binoculars will help). Mercury should look like a bright star a short distance to the right of the Moon.

If you fail that night or get clouded out, don't worry. For the next two weeks, Mercury will climb higher and higher in the west until it reaches greatest eastern elongation on the 16th (although visible in the western sky, Mercury lies east of the setting Sun, hence the name). On that date, the planet will be some 20 degrees from the Sun, remaining visible until about two hours after sunset. If you have a telescope, try viewing Mercury as it mimics the Moon's phases, going from a gibbous (nearly full) state in early April to "half Moon" around the 16th, to a thin crescent just before it slips back into the Sun's glare at month's end.

Eastern and western elongations provide the best opportunities to view Mercury because the planet at these times appears farthest from the Sun. Around eastern elongation, Mercury looks like an evening star after sunset. At western elongation, Mercury rises ahead of the Sun as a morning planet. In either case, the innermost planet never gets farther than about 23 degrees from the Sun, visible for two hours at most before sunrise or after sunset.

Our neighbor Venus also does the "Mercury Shuffle," but in a much more dramatic fashion. During elongation, our sister planet is a full 45 degrees from the Sun and is bright enough to be seen in broad daylight! And the phase changes are truly spectacular. We'll be sure to set you up with a ringside seat when Venus makes her next visit to the evening sky in late September.

Questions? Comments? Drop me a line at gchaple@astronomy.com. I enjoy reading your e-mails and try to incorporate your ideas into this column. Next month, we get ready for May's lunar eclipse, *which should* be a spectacular event. Clear skies!



**THE ELUSIVE INNERMOST PLANET, MERCURY,** and a crescent Moon will appear together early this month, although you may need binoculars or a finder to spot them. ROBERT L. JOHNSON

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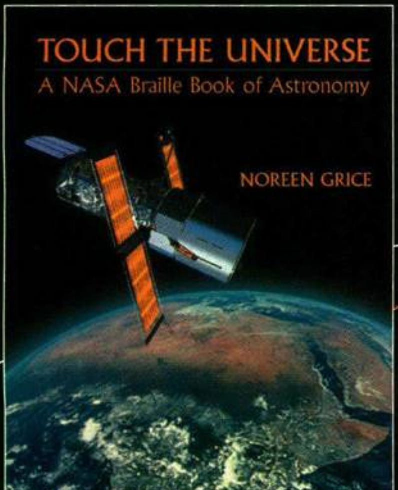
"A visually impaired person can still touch and smell a flower, or a tree, or an animal, but he or she could only imagine what an astronomical object is like…until now." —*Noreen Grice, from the book*



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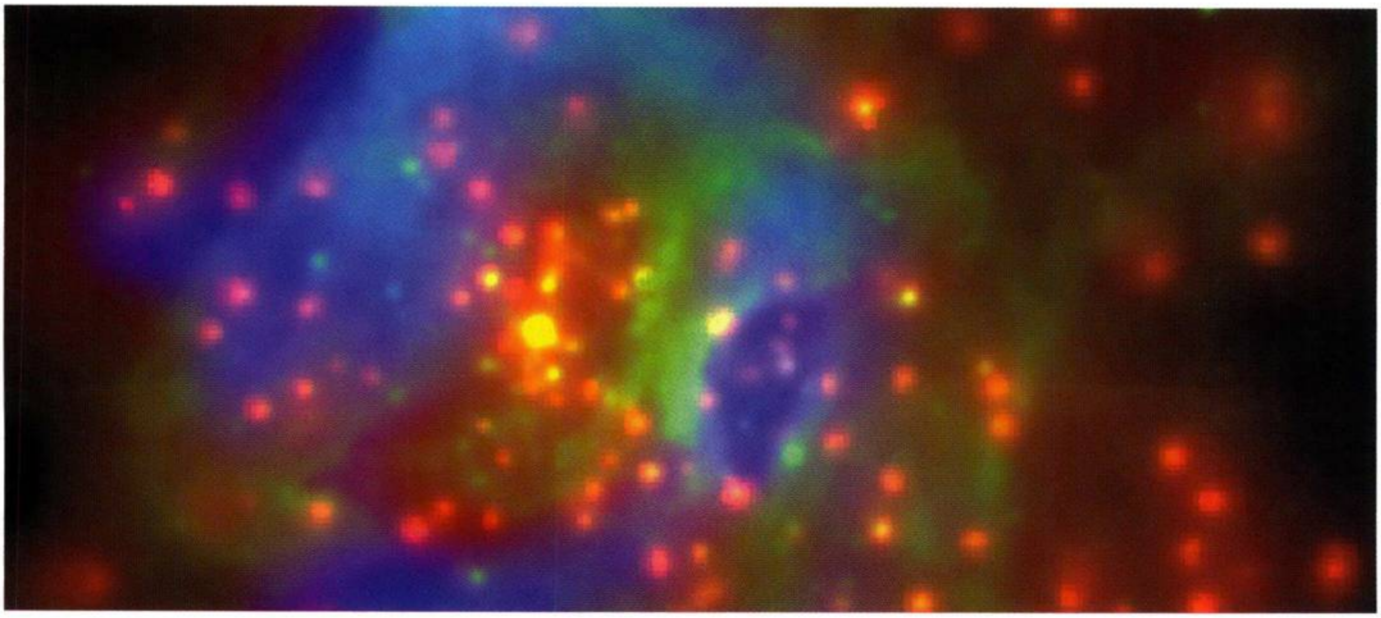
{ 04:2003 } NASA awarded an $824.8-million contract for the Next Generation Space Telescope, to be called the James Webb Space Telescope, to TRW Space and Electronics for design and construction of the telescope's primary mirror and spacecraft.

# news 04

Read all about it: Gamma-ray bursts, neutrino mass, the rings of Uranus, gravitational lens observation, looking earthward, and Yuri's Night.



**X RAYS MUTATE PRO-STELLAR DISKS** in the stellar nursery RCW 38. Driven by an unknown source, the x rays (red) permeate the space around young stars that appear in the infrared (green) and are surrounded by warm, radio-bright (blue) gas. X RAY: NASA/CXC/CFA/S. WOLK ET AL.; INFRARED: ISAAC/VLT; RADIO: ATCA

**STARS**

## X rays from the young

Just 6,000 light-years from Earth, a star-forming nebula is aglow in x-ray radiation. This small system, RCW 38, measures five light-years in diameter and houses thousands of very young stars. According to recent observations, this nebula is also home to a dark secret that accelerates electrons to extraordinary velocities, producing high-energy x-ray emission.

"The RCW 38 observation doesn't agree with the conventional picture," says Scott Wolk of the Harvard-Smithsonian Center for Astrophysics in Boston, Massachusetts. High-energy particles are typically produced by supernovae and in strong magnetic fields associated with black holes and neutron stars. These objects aren't observed in RCW 38.

It's possible that a supernova exploded in this nebula at some point in the past and has now faded from view, leaving behind a shock wave or neutron star that drives the magnetic field. "Regardless of the origin of the energetic electrons," says Wolk, "their presence would change the chemistry of protostellar disks in ways that could still be manifest billions of years later." The x-ray radiation may lead to the eventual formation of planetary systems with significant radioactive material.

— **PAMELA L. GAY**

26
United States

24 Merging galaxies
26 NASA's new Orbital Space Plane
28 Hubble observes gravitational lens
32 Infrared image of Hubble Deep Field

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**COSMOLOGY**

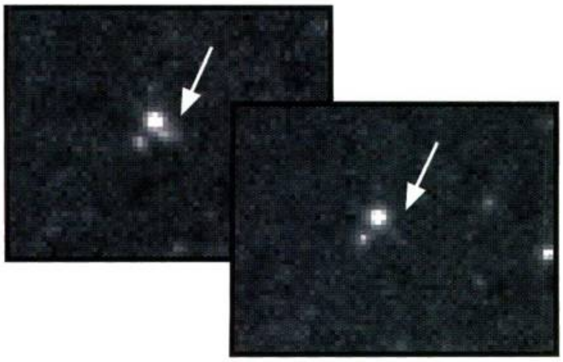
## Burst revealed

Gamma-ray bursts come in two varieties: those that optically glow, and those that don't. Now, thanks to fast-moving, dedicated telescopes, one of these "dark" bursts has been optically identified.

On December 11, 2002, NASA's High Energy Transient Explorer (HETE) spotted a 2.5-second burst of gamma rays. Within 22 seconds, it relayed the burst's position to observatories across the world. The ground-based RAPTOR (RAPid Telescopes for Optical Response) telescope was on-target and imaging just 65 seconds after the outburst, and other telescopes were also observing the field within minutes.

At stake was evidence to explain why some gamma-ray bursts have long-lasting afterglows, while others are essentially dark. Bursts are believed to be caused by massive star explosions and by binary mergers of black holes and/or neutron stars. In both scenarios a black hole is created in an energetic rearranging of matter that can create an afterglow by shocking surrounding dust and gas. "Dark" bursts were previously believed to be buried in thick clouds of material that blocked the burst's afterglow. These new observations indicate that the reverse may be true: There was no material around the burst's progenitor to be shocked into glowing.

Within two hours of the December 11 burst, the afterglow had completely faded away. If it hadn't been for HETE's quick identification and the rapid pointing of telescopes, this burst might have been optically missed forever. — **P. L. G.**



**THE GROUND-BASED RAPTOR** telescope imaged a 2.5-second gamma-ray burst just 65 seconds after the outburst (left).

P. WOZNIAK, W.T. VESTRAND ET AL., RAPTOR PROJECT, LANL

**OBSERVATORY NEWS**

## Make way for MIDI

**To the delight of its creators, the state-of-the-art MID-Infrared interferometric instrument (MIDI) successfully performed its first observations with the VLT Interferometer (VLTI) at the Paranal Observatory in Chile.**

**COOL AND COLLECTED,** the MID-Infrared interferometric instrument (MIDI) is installed in the VLTI instrument room.

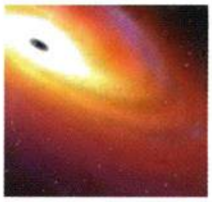
ESO

**The international production team gathered on the morning of December 15, 2002, to witness first light. Light from two of the 8.2-meter VLT telescopes (ANTU and MELIPAL) was successfully combined to form a single interferometric image of the star Epsilon Carinae.**

**This is the first time telescopes with such large mirrors have been used for mid-IR interferometry. — MATT QUANDT**

**SATELLITE NEWS**

## Integrating wavelengths



**CYGNUS X-1,** a black hole system, was Integral's first target.

ESA

The European Space Agency's high-energy Integral observatory became fully operational in December 2002 following its October 17 Russian launch. Integral (INTErnational Gamma-Ray Astrophysics Laboratory) carries two powerful gamma-ray instruments as well as x-ray and optical monitors. This multi-wavelength observer is on a five-year mission to explore the high-energy universe and investigate exploding stars and their collapsed remains.

"X-ray and gamma-ray astronomy is a pathfinder to unusual objects," states Arvind Parmar, acting Integral Project Scientist at ESA. "At optical wavelengths, the number of stars is staggering. At x-ray and gamma-ray wavelengths, there are fewer objects, but the ones that remain are the really peculiar ones."

As a first test, Integral observed the enigmatic object Cygnus X-1. Scientists were pleasantly surprised when Integral captured its first gamma-ray burst. — **JAMES OBERG**

**COMPACT GROUPS**

## Tearing up the dance floor

At first glance, the breathtaking galaxy collection called Seyfert's Sextet appears to be a playful square dance. However, a new Hubble Space Telescope image of the group, also known as NGC 6027, reveals its activity as truly destructive.

In the 1940s, astronomer Carl Seyfert noticed that NGC 6027 in Serpens wasn't a single galaxy, but a collection of six systems appearing to occupy a space smaller than that of our Milky Way. Later studies revealed that the group contains only four gravitationally bound galaxies.

The Hubble image reveals scars from the gravitational interactions of this tight group. Galaxies are now deformed, with halos of stars pulled from their warped disks. Eventually, these dance partners will merge into one giant galaxy. Astronomers predict the merger will take billions of years to finish. — **VANESSA THOMAS**

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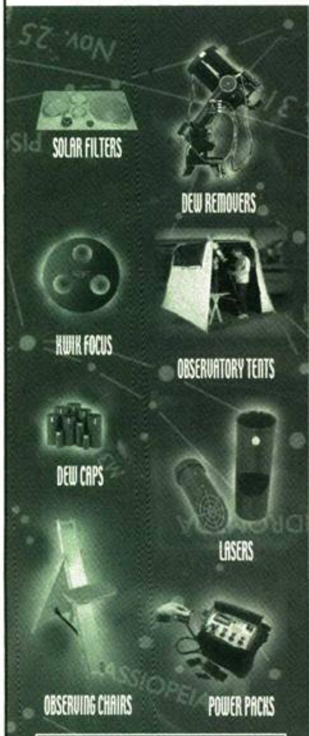

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PARTICLE PHYSICS

## Neutrino mass

For many years, researchers have struggled to determine if neutrinos and anti-neutrinos, subatomic particles created in nuclear reactions, are pure energy like photons, or a composite of energy and matter like electrons. After a 145.1-day experiment, a team of international experts has shown that neutrinos do have mass.

**SCINTILLATING FLUID FLICKERS** deep below ground when it is struck by electron anti-neutrinos at KamLAND. LBNL KAMLAND

Neutrinos and their antimatter twins, anti-neutrinos, pass easily through most materials — including lead — without interacting. This makes them extremely hard to detect and measure. To find them, scientists have devised chemical soups that flicker when neutrinos interact with atoms in the broth.

By calculating the fraction of neutrinos from a nuclear reaction that should pass through a chemical mixture and interact, scientists predict how many neutrinos should be detected.

Preliminary solar neutrino counts were substantially lower than expected, indicating that neutrinos might have mass that allows them to oscillate from a detectable to an undetectable form by altering how much of their energy is stored in matter.

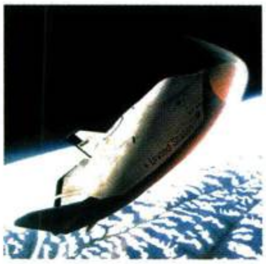
A new Japanese detector, KamLAND (Kamoka Liquid-scintillater Anti Neutrino Detector), measured a shortfall in electron anti-neutrinos from nuclear reactors. This shortfall proved neutrinos have mass. — **P. L. G.**

## NASA introduces the Orbital Space Plane project

**THE X-38 SPACE PLANE,** with already-tested technologies, will serve as a starting point for designers of the new Orbital Space Plane. DRYDEN FLIGHT RESEARCH CENTER / TONY LANDIS (NASA)

In an ironic turnabout, a new generation of NASA space engineers has been tasked with designing human spacecraft to be launched in much the same style as the old Apollo and Gemini capsules. It will be used with the International Space Station (ISS). The vehicle will be the first new human spacecraft built by NASA in thirty years. It may outwardly resemble designs developed and tested in the 1960s but will internally incorporate many advanced materials and components.

The project, called the "Orbital Space Plane" (OSP), will take about six or seven years to become operational. Once built, it will carry passengers into orbit, dock with the space station, remain there as a lifeboat, and then return to Earth with crew and cargo. The vehicle will be reusable, with perhaps only three or four being built. The OSP will be launched aboard a new generation of expendable boosters now in use at Cape Canaveral.



**THE ORBITAL SPACE PLANE** will carry astronauts to and from the International Space Station and serve as a lifeboat for American astronauts in case of emergency. NASA

The promised vast capabilities of the ISS remain bottlenecked by the crew size-limit of three. Currently, all crewmembers must be able to fit into the cramped Russian Soyuz spacecraft that can serve as a lifeboat.

An allowance for a larger crew size and larger crewmembers is urgently needed to allow other international partners — Europe, Japan, and Canada in particular — to have researchers aboard the station. The Russians intend to use their Soyuz visits to bring their own cosmonauts up and down, so NASA needs its own lifeboat.

NASA had been developing the X-38 to serve as an emergency vehicle for up to seven crewmembers and had a planned completion goal of 2005. Unfortunately, the project's costs soared out of control, and it was canceled last year. Project managers have now conceived a simplified OSP and added the requirement that it be able to carry passengers into orbit as well as back.

The spacecraft will be shaped like a lifting body — the small-winged, sliced bullet design that was first tested four decades ago. This shape promises gentler deceleration and more accurate landings than the conical capsules of the Mercury, Gemini, Apollo, and Soyuz programs. "While the OSP is a new vehicle," says Bill Rothschild, Boeing's chief OSP designer, "it draws on the legacy and knowledge of more than 40 years of human space flight." — **J. O.**

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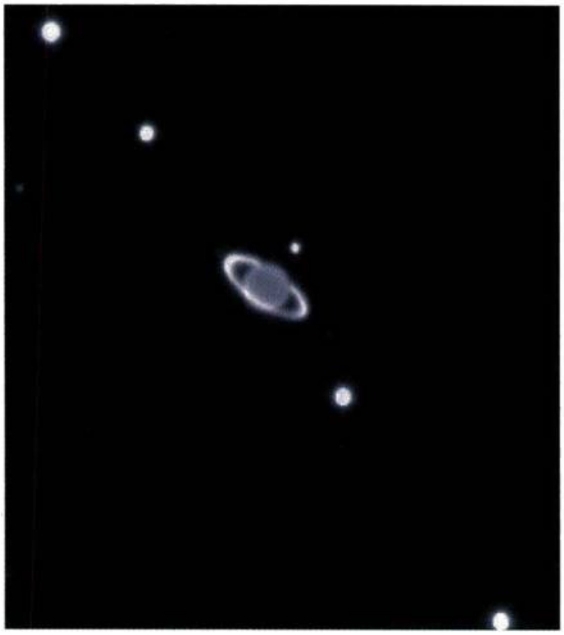
WHAT'S HOT: At the 2002 AAS meeting in Seattle, WA, numerous groups announced plans to look for extrasolar planets via the slight dimming that occurs when they pass in front of their star. Check this section next month for more information.

GAS GIANTS

## The other Lord of the Rings: Uranus



**THE RINGED PLANET URANUS** is oriented remarkably like its ringed sibling Saturn in this infrared image taken November 19, 2002, with the 8.2-meter VLT ANTU telescope. ESO

Highly reflective in optical light, Saturn's rings are boldly visible to every casual observer. If we could retune our eyes to other wavelengths, the rings of Uranus could appear just as starkly against the sky.

Viewed in the infrared with the 8.2-meter ANTU telescope at the ESO Paranal Observatory in Chile, Uranus appears strangely reminiscent of its more famous ringed sibling, Saturn. Uranus's rings were first discovered in 1977 during a stellar occultation. Viewers onboard the Kuiper Airborne Observatory and at the Perth Observatory in Australia saw the star briefly fade and re-brighten before and after it passed behind the planet. They correctly attributed this variation in brightness to dark rings that temporarily eclipsed the starlight. Uranus's rings were imaged by the Voyager 2 spacecraft in 1986.

Uranus's rings stand out strongly in the infrared because their icy material is efficient at reflecting sunlight at this wavelength. The planet's infrared shine does not wash out the rings because Uranus's methane atmosphere only poorly reflects infrared light. — **P. L. G.**

SKY DISCOVERIES

## Amateur comet

In the predawn hours of December 14, 2002, Japanese amateur astronomer Tetuo Kudo observed a comet in the constellation Hercules. Kudo discovered the swift-moving object, C/2002 X5, in the northeast sky with a pair of 20 by 120 binoculars. He estimated its magnitude at 9.5. The discovery marks the first comet to bear Tetuo Kudo's name.

**COMET C/2002 X5** (Kudo-Fujikawa) had faint beginnings, as this December photo shows. ESO

In a discovery that reemphasizes the importance of amateur comet hunting, Kudo observed the comet in an area of the sky where computer sky surveys do not scan.

The next day, independent of Kudo, Shigehisa Fujikawa used a 6" reflector to find the comet. This marks the sixth comet to carry Fujikawa's name. — M. Q.

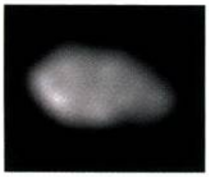
SOLAR SYSTEM

## Amalthea, a pile of rubble

Before crashing into Jupiter this September, the Galileo spacecraft is sure to reveal a few more jovian surprises. Its latest came last November, when it flew within 99 miles (160 km) of Jupiter's inner moon, Amalthea.

"The density is unexpectedly low," reports John Anderson of NASA's Jet Propulsion Laboratory. "Amalthea is apparently a loosely packed pile of rubble."

Amalthea's density is near that of water ice. But the red-hued moon isn't just an icy chunk, astronomers believe. It's "mostly rock with maybe a little ice," says Galileo project scientist Torrence Johnson.



**APPEARING SOLID,** Amalthea is really packed rocks and ice. NASA / JPL

Most of its volume is empty space between ill-fitting, boulder-sized chunks that are held together by their mutual gravity.

"This finding supports the idea that the inner moons of Jupiter have undergone intense bombardment and breakup," Johnson adds. "Amalthea may have formed originally as one piece, but then was busted to bits by collisions." — **V. T.**

HUBBLE IMAGES

## Bent light

Using an innovative and fascinating method to capture images with IMAX movie quality sharpness, the new Advanced Camera for Surveys on the Hubble Space Telescope reveals galaxies previously beyond Hubble's reach. ACS combines cutting-edge technology with Einstein's physics phenomena, "gravitational lensing," to produce a lens 2 million light-years wide. Combining instruments and physics results in unprecedented views of the universe. Recently, ACS peered at the center of one of the most distant galaxy clusters known, Abell 1689, located 2.2 billion light-years away. ACS allows astronomers to study gravitational lensing like never before since it is five times more sensitive than the current and now primitive Hubble cameras. — **M. Q.**

**THE CURVATURE OF SPACE** bends light around massive galaxies in the distant universe. NASA

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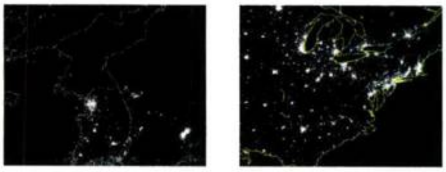
**ORBITAL MONITORING**

## Night-vision satellite

Night-vision goggles have become standard equipment for nocturnal hunters and soldiers working at night. This equipment allows humans to see as snakes — in infrared light that is given off by warm objects such as animals, steaming coffee pots, and hot lights. This equipment is not confined to Earth, however. The U.S. Air Force Defense Meteorological Satellite Program (DMSP) flies four satellites in sun-synchronous orbits that image the entire surface of Earth twice a day. Among its many sensors, the DMSP has an Operational Linescan System that, like night-vision goggles, allows it to see in low light conditions, and to image Earth at night using thermal infrared radiation.



**NORTH KOREA,** (left) lacking in infrastructure and low in electricity, has literally entered a new "dark" age. South Korea is home to 48.3 million people, and 22.2 million people live in North Korea. **NOT FRIENDLY TO ASTRONOMERS,** (right) but beautiful from space, the eastern half of the United States is home to roughly 171 million people (and too many lights!). NOAA / USAF DMSP

Astronomers are most familiar with the DMSP from its sensational mosaics of Earth at night that show light and light pollution from cities, fires, fishing boats, and even volcanoes. While these images make great wall hangings, the DMSP's primary mission is not to provide pretty posters. Instead, the DMSP is used to monitor forest fires, changes in population density via light density, and also to track clouds at night. The military also uses the DMSP to monitor the efficiency of nighttime bombing raids and to track nighttime enemy/terrorist movements. — **P. L. G.**

## Upside-down telescopes

Satellite and aerial photography has long been a valuable tool for many industries, and in the past year image providers have become nearly ubiquitous on the Internet. Now, even the average person can view the world through these upside-down telescopes.

Not all providers offer the same coverage, and it may take some trial and error to find the best images of your area. Within the continental United States, it should be possible to find 1-meter (or better) resolution color images for almost any major city, but as the population decreases, so too does the coverage.

Perhaps the best overall source is GlobeXplorer, a company that primarily collects and distributes aerial photographs. By browsing (globexplorer.com), you'll have access to what appears to be their entire catalog, but the images are all heavily watermarked. As of this writing, most of the same images are available on MapQuest (mapquest.com) without the watermarking if you have an AOL Instant Messenger ID. Look up the address via the normal MapQuest interface, and then click the "Aerial Photo — Network Special" tab above the map.

**KALMBACH PUBLISHING CO.,** the parent corporation of *Astronomy* magazine, is housed in this building. In this noontime shot many cars have gone (with their owners) to lunch. GLOBEXPLORER

If your area isn't within GlobeXplorer's coverage, your next best bet for high-resolution images is United States Geological Survey (USGS) aerial imagery, which typically has 1-meter resolution in black and white. The most well-known interface is Terraserver, by Microsoft (terraserver.homeadvisor.msn.com).

Another good source of the USGS imagery is the TerraFly system (terrafly.fiu.edu). TerraFly is a research project sponsored by a collection of federal agencies, corporations, and educators. TerraFly offers several improvements over the standard commercial interfaces. It allows users to pan without reloading and to access local geographical information through overlays. With a simple click, users can open a window with all available data for a specified point.

If you just want to view interesting images, Space Imaging (spaceimaging.com) offers a great gallery of satellite images. Subjects range from the aftermath of September 11, 2001, to famous international landmarks to images of a camp from CBS's "Survivor" series.

If you would rather focus on beauty than geography, check out the Landsat-7 false color images at the USGS's EarthExplorer website (earthexplorer.usgs.gov). The interface leaves something to be desired, but if you can fight your way through it, you'll be rewarded with spectacular images. Choose "Enhanced Thematic Mapper Plus" for the Data Set Selection, pick a place, and see what you can find. — **MATT DUNN**

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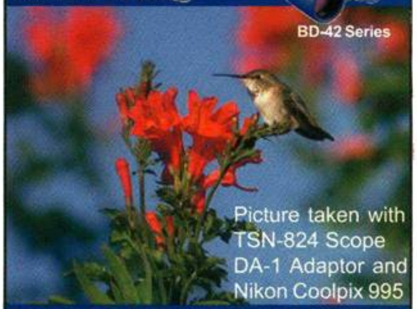

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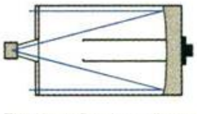

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WHAT'S NEW: Scientists studying the Orion and Carina nebulae revealed the possibility of planetary disks forming around young stars. This hints that high-density environments may have planets. More details in May.

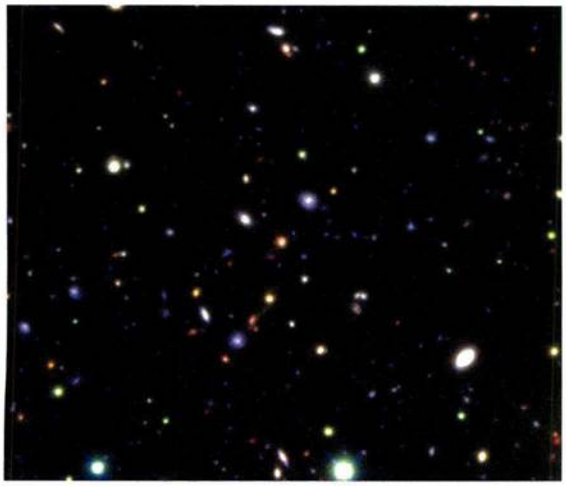
EXTRAGALACTIC ASTRONOMY

# Infrared Deep Field South

Sometimes the most interesting things are invisible to the human eye, or in astronomy, in visible light. Until recently, our deepest images of the early universe were gleaned from incredibly long Hubble Space Telescope images taken in visual wavelengths. The Hubble Deep Fields described an early universe where galaxies were still forming, and systems were rich with star formation. These images, however, were biased by wavelength, where young, hot, blue stars were easily observed. Turning to the infrared, the Very Large Telescope revealed well-formed giant red galaxies that had kept their photons just out of reach of the venerable HST.

The 8.2-meter VLT ANTU telescope took a series of near-infrared images with the ISAAC multi-mode instrument. The expansion of the universe causes the majority of the light from distant galaxies to be redshifted to infrared wavelengths. With a total $K_s$–band (2.16 micron) exposure time of 35.6 hours, this image reveals the most distant galaxies ever seen. Because of the finite speed of light, these galaxies appear as they were 2 billion years after the universe formed.

Remarkably, even at that early epoch, these giant galaxies were already well formed, with spiral arms and limited star formation. This revelation forces astronomers to rethink their timescales for galaxy formation and evolution, but confirms the theory that large galaxies in dense regions of space were among the first to form. — **P. L. G.**



**EXTENDING THE HUBBLE DEEP FIELD SOUTH** into the infrared, the ANTU reveals galaxies that are barely detected by the Hubble Space Telescope. ESO

OBSERVATORY NEWS

## Virtual Observatory sees first light

**Just as billions of individuals around the world use the Internet to keep in touch with scattered friends, astronomers will soon use Internet technology to coalesce scattered astronomical archives into a coherent "virtual observatory."**

**The state-of-the-art Virtual Observatory is an international initiative to allow electronic access to previously secluded data archives of space and ground-based observatories.**

**Europe's Astrophysical Virtual Observatory's "first light" came in January 2003 at Jodrell Bank Observatory in Manchester, England. — M.Q.**

**THE "ENGINEERING FORCES"** behind the construction of the Astrophysical Virtual Observatory: M. Leoni (left) and M. Dolensky (right). ESO

SOLAR SYSTEM

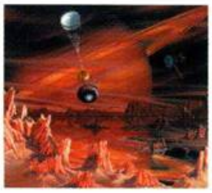
## Saturnian origins

Saturn's planet-sized moon Titan is ripe with the stuff of life. Its atmosphere is composed of nitrogen and some methane. This allows for the fast assembly of long organic molecules. While Titan is too cold for life, it may provide a model for how the building blocks of life — organic materials — can be formed.

"Titan has organics, but in what form and how much is not clear. These molecules are generated in the atmosphere and over time are deposited on the moon's surface," says University of Arizona researcher Jonathan I. Lunine.

Could Titan host primitive life? "It is not the right place; it is too cold," says Lunine. "Others have argued that life could exist in the deep interior of Titan where liquid water may be available all the time . . . I do not see Titan as the place to search for life. But it certainly is the place to explore the chemistry that may have led to its origin."

Cassini-Huygens space probe, due to reach Saturn in 2004, will perform this exploration. — **P. L. G.**



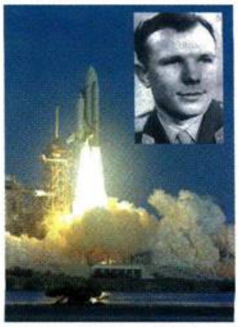
**THE HUYGENS PROBE** will drop to Titan, where it will explore the moon's surface. NASA/CASSINI/JPL

THIS DAY . . .

## It's Yuri's night, oh what a sight!

Two significant events pushed space exploration forward on the day of April 12, twenty years apart. In 1961, Yuri Gagarin broke the surly bonds of space and became the first human to orbit the globe. In 1981, cheers and sighs of relief were heard as the space shuttle Columbia became the first reusable spacecraft launched.

To honor these accomplishments, an international party takes place every year. In 2002, Yuri's Night was held in 45 countries on seven continents, while the crew of the International Space Station honored Yuri and other humans' achievments in space. For more information or to find the party nearest you, visit yurisnight.net.
— **KELLEY KNIGHT**



**ON APRIL 12, 1961,** Cosmonaut Yuri Gagarin (inset) became the first man to fly into space. TASS/AP

**ON APRIL 12, 1981,** the Space Shuttle Columbia became the first reusable spacecraft. It carried two astronauts. NASA

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CGE 800

## Introducing the completely new CGE Series. Designed and engineered to meet a mounting demand.

**Your wait is over**. You've been asking us for a complete selection of our top-of-the-line Schmidt-Cassegrains mounted on a beefy computerized German Equatorial mount. We proudly announce the CGE Series — CGE 1400-14", CGE 1100-11", CGE 925-9.25", and CGE 800-8".

**SCT, OTA and CGE Computerized Mount — Portability and Stability In A GoTo System.** All CGE's can be quickly disassembled into easy to handle transportable components — even the CGE 1400! Recognized for superior stability, German Equatorial mounts eliminate the tuning fork like vibration associated with fork mounted telescopes. The new CGE's are ideal for viewing objects in every part of the sky – even in the North where fork mounts have difficulty pointing.

**Easy to polar align** – German Equatorial mounts are the choice of the best astrophotographers.

**Easy to counter balance** – In both RA and Dec, for smooth photographic quality tracking.

◄ CGE 1400
CGE 1100 ►

The CGE Mount is made of CNC machined aluminum and stainless steel and features the NexStar® control system.

**Drive Base Features:**

- Autoguide port
- PC port
- 3 Accessory Ports
- Real time clock – maintains time even when powered down
- Strain relief power cord cable protection
- Backlit power switch

**Drive System:**

- U.S. manufactured Pittman 12V DC servo motors
- U.S. manufactured Berg bronze drive gear mated with stainless steel worm shafts
- 2 point RA clutch system for no slip pointing precision

**Tripod Features:**

- Dual Leg Support
- Center leg brace provides outward preload
- *Lower leg brace provides* inward preload
- Extendable powder-coated carbon steel legs

| OPTICS | CGE 800 | CGE 925 | CGE 1100 | CGE 1400 |
|---|---|---|---|---|
| Focal length | 2032mm; f/10 | 2350mm; f/10 | 2800mm; f/10 | 3910mm; f/11 |
| Secondary Obstruction | 2.7" | 3.35" | 3.75" | 4.5" |
| Resolution (Rayleigh) | .68 arcseconds | .59 arcseconds | .50 arcseconds | .39 arcseconds |
| Coatings | StarBright® | StarBright® | StarBright® | StarBright® |
| Optical Tube | Carbon Fiber | Aluminum | Carbon Fiber | Aluminum |
| Fastar Compatible | Yes; f/1.95 | No | Yes; f/2 | Yes; f/2.1 |

| STD. ACCESSORIES | CGE 800 | CGE 925 | CGE 1100 | CGE 1400 |
|---|---|---|---|---|
| Eyepiece | 25mm Plössl | 25mm Plössl | 40mm Plössl | 2" 40mm Barrel |
| Star Diagonal | Prism Diagonal | Prism Diagonal | Prism Diagonal | 2" Mirror Diag. with $1^{1/4}$" Adapter |
| Finderscope | 6x30 | 6x30 | 9x50 | 9x50 |
| Power Supply | Car Battery Adapter | Car Battery Adapter | Car Battery Adapter | Car Battery Adapter |
| Counter Weights | 1-11lb. | 1-25lb. | 1-25lb. | 2-25lb. |

## PRICING

**CGE Computerized Mount (#91524):**
**$2999** + $95 Shipping & Handling
**CGE 800 (#11058):**
**$3499** + $105 Shipping & Handling
**CGE 925 (#11059):**
**$3799** + $145 Shipping & Handling
**CGE 1100 (#11061):**
**$4149** + $245 Shipping & Handling
**CGE 1400 (#11063):**
**$5799** + $295 Shipping & Handling

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**Optional Accessories:**

- 12V DC Rechargeable Power Supply (#18774)
- 2"-70° Apparent Field, Axiom Eyepieces
- Reducer Corrector; f/6.3 (#94175)
- CN16 GPS Accessory (#93963)

## Specifications

### Software

40,000 + Objects
400 User defined objects
Hibernate — Maintains alignment even while powered down
Polar alignment routines for Northern and Southern hemisphere
Filter limits — Displays only objects above the horizon
Permanent programmable PEC — Corrects periodic tracking errors inherent in all worm drives
Smooth ramping of slew motors to reduce wear on drive train

### Electronics

Home sensors on RA and Dec axes
Real time clock
Fail safe slew limit switches in RA
12V DC Servo Motors with integrated optical encoders, 256CPR used in quadrature
Encoder resolution: .11 arcseconds

### Mechanics

CNC machined aluminum and stainless steel components

### RA axis

- 1" solid ground stainless steel shaft
- Two Preloaded .9835" I.D. x 2.047" O.D. tapered roller bearing
- One 4.724" O.D. x 3.543" I.D. thrust bearing
- 180 tooth, 5.625" diameter enveloping bronze gear preloaded to maintain gear mesh while clutch tension varies, manufactured to AGMA 10 quality.
- .4375" diameter precision 303 stainless steel worm, manufactured to AGMA 10 quality
- 2 point RA clutch system pre-loading a 4.65" stainless steel disk for no-slip drive and pointing precision

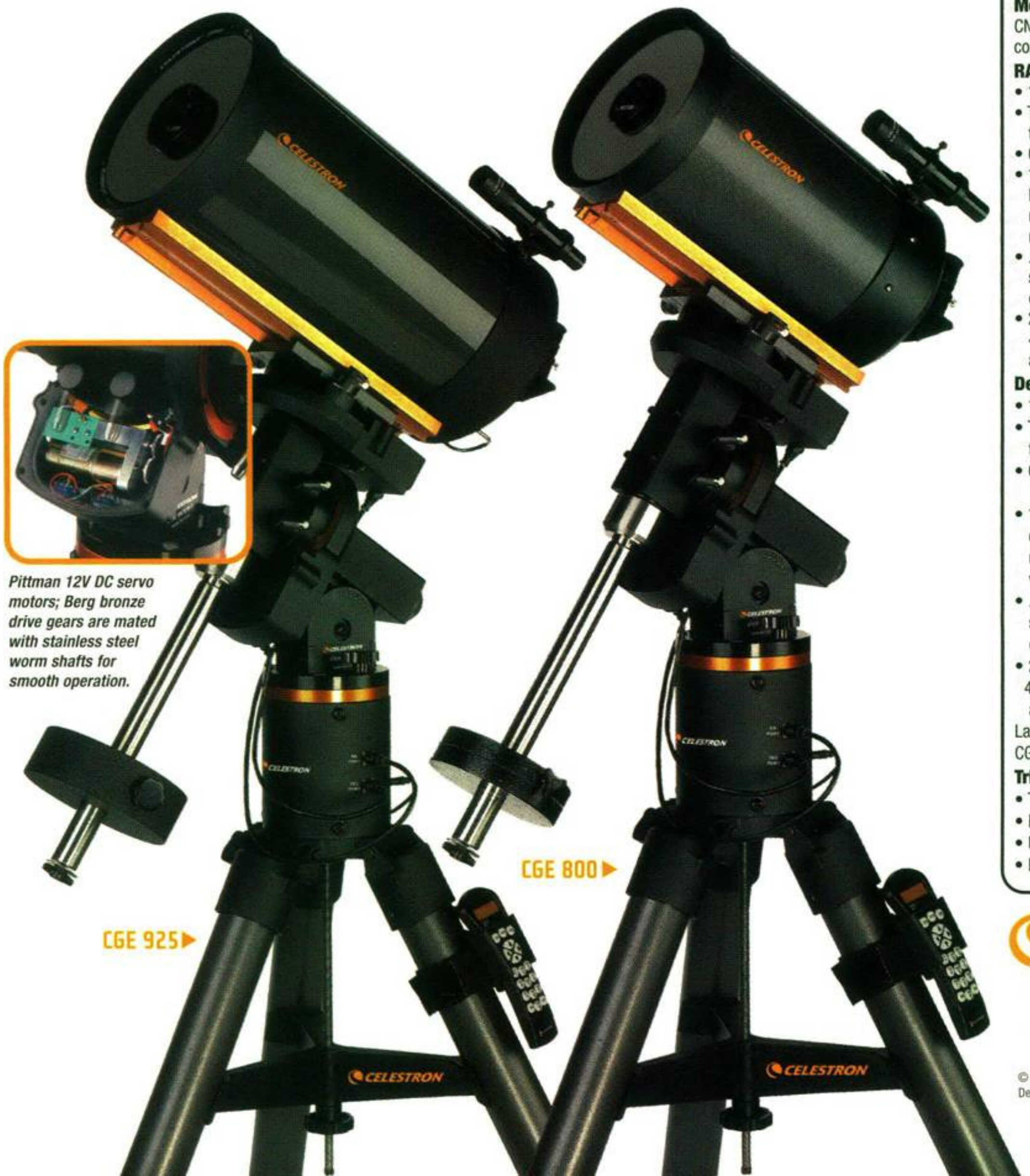
### Declination axis

- 1" solid ground stainless steel shaft
- Two Pre-loaded .9835" I.D. x 2.047" O.D. tapered roller bearings
- One 3.250" O.D. x 2.500" I.D. thrust bearing
- 180 tooth, 5.625" diameter enveloping bronze gear preloaded to maintain gear mesh while clutch tension varies, manufactured to AGMA 10 quality.
- .4375" diameter precision 303 stainless steel worm, manufactured to AGMA 10 quality
- 2 point Dec clutch system pre-loading a 4.65" stainless steel disk for no-slip drive and pointing precision

Latitude Range: 10° to 60°
CGE Maximum Payload: 65 lbs.

### Tripod

- Tripod height: 36" to 50"
- Leg material: cold rolled carbon steel
- Upper leg diameter: 2.75"
- Lower leg diameter: 2.375"



*Pittman 12V DC servo motors; Berg bronze drive gears are mated with stainless steel worm shafts for smooth operation.*

**CELESTRON**®

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*"We ran through the alignment procedure during evening twilight and observed throughout the entire night without missing a beat...and every object that we commanded the scope to point at ended up in the field of a low-power eyepiece."*
*"The optics in the NexStar loaned to us were some of the finest I can recall in a Schmidt-Cassegrain, but if anything the optics in the scope we purchased at random were even better."*
*–Dennis di Cicco*
*"The NexStar 11 GPS: Beauty and Brains"*
*Sky and Telescope*
*February 2002*

# A telescope that combines the design features, engineering, performance, and value of the NexStar® 11GPS doesn't come out of the *Blue*.

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NexStar® 11GPS
**$2999***
+ $125 Shipping & Handling
Includes Standard Heavy-Duty Adjustable Tripod

At Celestron, we know that the whole is greater than the sum of all of its parts. That's why we design, engineer, and manufacture the NexStar 11GPS telescope from the beginning with features and performance that add up to a whole lot more telescope than the competitor's 8", 10" and 12" GPS telescopes — ***and a better value.***

**Here's why:** Compare the design features and construction of the NexStar 11GPS ( as well as the NexStar 8GPS) to the competitor's 12", 10", and 8" GPS telescopes. Every component of the NexStar 11GPS, from its rugged integrated drive base and fork arm design to the unique carbon fiber optical tube assembly has been designed specifically for this model NexStar telescope. Only Celestron matches and meticulously hand-figures each individual telescope optical system.

## Understanding Resolution.

***Do coatings affect resolution?*** No! When comparing telescopes, it's extremely important to clearly understand the relationship between coatings and resolution. ***Fact: Resolution is a function of aperture.*** ***Coatings only affect light transmission***. It is a function of aperture or diameter of the objective lens. Rayleigh's Criterion defines resolution as: $\theta=1.22*\lambda/D$, where $\lambda$ is the wavelength of light, D is the diameter of the objective lens, and $\theta$ is the resolution in radians. Image brightness is a function of aperture, focal ratio, and system's light transmission efficiency. ***StarBright® coatings have been standard on all of our Schmidt-Cassegrain telescopes since 1983 AT NO ADDITIONAL COST***. For primary and secondary mirrors, StarBright coating is a precise multilayer application of Al, $SiO_2$, $TiO_2$, and then another layer of $SiO_2$ — all to maximize reflectivity. On the corrector lens we apply precise layers of $MgF_2$ to both surfaces to maximize transmission.

*The dark-adapted (scotopic) eye's peak sensitivity is at 510nm. The sensitivity drops off dramatically on either side of 510nm. In fact, as the wavelength approaches 400nm, the eye's sensitivity goes to almost 0%. The same is true as the wavelength goes to 600nm. Celestron's StarBright® Coatings are designed to peak at 510nm, the peak sensitivity of the scotopic eye. Celestron offers these coatings at no additional cost to the consumer. The chart below shows the transmission at 510nm for both Celestron and competitor's large aperture SCT telescopes.*

**Transmission at 510nm for all Celestron large aperture SCT's and competitor's SCT's**

| | | |
|---|---|---|
| NexStar 8" | 87% | No Additional Cost |
| NexStar 9.25", 11", 14" | 85% | No Additional Cost |
| Competitor's Standard Coatings - all SCT's | 77% | No Additional Cost |
| Competitor's UHTC | 86% | Cost: $175 (8"), $235 (10"), $295 (12") |

Competitive information obtained from December, 2002 issue of *Sky and Telescope*.

## NexStar 11GPS. Quality from the inside out.

***Carbon Fiber Tube* — Strong and lightweight with 1/4 of the thermal expansion of an aluminum tube. Scratch and dent resistant.**

***Optical Tube Assembly Outer Rails* — An outer rail on each side of the optical tube provides rigid, flex-free movement. Mounting tolerance allows cell to contract and expand.**

# NexStar quality and reliability. Designed in. Not added on.

## COMPARISON OF DESIGN FEATURES

This chart compares the significant design and engineering features of the NexStar 11GPS with competitor's 10" and 12" GPS telescopes.*

| Feature/Specification | NexStar 11GPS | Competitor's 10" | Competitor's 12" |
|---|---|---|---|
| Mirror Coatings | StarBright*; 5-step multilayer | Standard; ( Enhanced Coatings $235 ) | Standard; ( Enhanced Coatings $295 ) |
| Fork Arm | Dual fork tine cast aluminum with integrated hand control receptacle. Fork arms are long enough to permit optical tube to swing through | Dual fork tine cast aluminum; hand control attaches to fork arm with external bracket. | Dual fork tine cast aluminum; hand control attaches to fork arm with external bracket; fork arms not long enough to allow optical tube to swing through |
| Leveling Technique | Internal switch - levels the tube to the mount to the accuracy of 1 arcminute; Usable for both Alt/Az and equatorial | Ground level switch; only useful for Alt/Az | Ground level switch; only useful for Alt/Az |
| Cord Management | Internal slip ring design. Power is mounted to non-rotating part of drive base. Accessory ports rotate with top of drive base | Requires internal hard stops to avoid tangling and disconnecting wires; accessory ports do not rotate with telescope which can cause cords tangling | Requires internal hard stops to avoid tangling and disconnecting wires; accessory ports do not rotate with telescope which can cause cords tangling |
| Carrying Handles | Ergonomically designed for ease of lifting | Attached to front of fork arms | Attached to front and back of fork arms |
| Motors | Pittman mfg. in U.S.A.;12V DC Servo; quiet | Unknown; very noisy | Unknown; very noisy |
| Gears | Berg mfg. in U.S.A.; 5.625" precision bronze gears on both axes; 180-tooth; mated with stainless steel worm shaft | 5.75" aluminum gears on both axes | 5.75" aluminum gears on both axes |
| Bearings | 9.5" roller azimuth bearing | 4" dia. polar bearings | 4" dia. polar bearings |
| Focusing Mechanism | Two (2) preloaded ball bearings | Bushing and washer | Bushing and washer |
| Optical Tube | Carbon Fiber; reduces thermal expansion; 4x less than aluminum | Aluminum | Aluminum |
| Fastar Compatible | Yes | No | No |
| Weight of Telescope | 63 lbs. | 62 lbs | 75 lbs |
| GoTo Precision | 1.5 arcminutes | 2 arcminutes | 2 arcminutes |
| Boot-up Time | 1-1.5 sec. | 20-25 sec. | 20-25 sec. |
| GPS Alignment Time | 2.5 min. | More than 4.5 min. | More than 4.5 min. |
| Quick Align | Yes | No | No |
| Database Filter Limits | Automatic filter limits for named objects list | No database filter limits for custom object lists | No database filter limits for custom object lists |
| **Price**** | **$2,999 + $125 S&H = $3,124** | **$2,495 + $145 S&H + $235 for Enhanced coatings = $2,875** | **$2,995 + $215 S&H + $295 for Enhanced coatings = $3,505** |

## How you can tell wrong from right.

Celestron strongly believes that the only way to design and manufacture our NexStar GPS telescopes is the ***right way***. The right way means understanding what expectations our customers have when they make an investment in our products, and designing and manufacturing telescopes that meet or exceed their expectations. That means paying attention to details and not cutting corners. Compare the following examples of why we believe that we have designed the NexStar 8GPS and 11GPS the right way and what we believe is wrong with the design of the competitor's GPS telescopes. Consult the chart to the left for an additional comparison.

### Their Way:

- The competitor's GPS antenna is partially obstructed by the finderscope.
- When the base rotates, cables can easily wrap around the fork arms and become entangled.
- Carrying handles are poorly designed and located making it difficult to lift the telescope.
- Boot-up time can take as much as 20-25 sec.
- Hand control displays objects below the horizon.
- Motors and gearbox are noisy.
- The competitor's 10", and 12" drive base is undersized.
- The OTA (Optical Tube Assembly) on the competitor's 12" will not swing through and clear the drive base; the fork arms have spacers to attach to the base.
- The complete optical system is not hand-figured.
- The hand control is attached to a bracket with the cable hanging loose.
- Enhanced optical coatings cost extra
- Focus mechanism uses bushings intead of ball bearings.

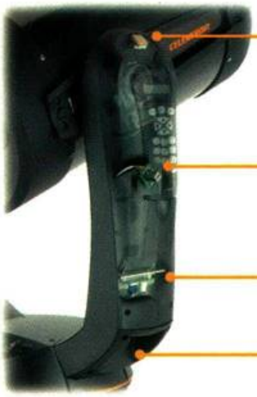
### Our Way:

- Celestron's GPS antenna is not obstructed by the finderscope.
- Celestron's drive base design eliminates any potential for cord/cable wrap.
- Carrying handles are integrated into fork arms to make lifting and transporting easier.
- Boot-up and alignment are fast and easy.
- Hand control has many advanced features and is user-friendly; only shows objects above the horizon.
- High quality precision gearing ensures quiet, precise operation.
- Large diameter drive base and bearing track provides maximum stability. Especially important when equatorially mounted.
- Carbon fiber tube minimizes thermal expansion/contraction; important for astrophotography or CCD imaging.
- Mirror shift minimized through use of precision bearings.

---

* Version Tested: 1.0b Telescope Serial #01039 All comparative information obtained from User Manual for this model.

**Prices obtained from December, 2002 issue of *Sky & Telescope*
Set-up Information: Starting Position: Alt.= -90 and Az =0
Date: 09.18.02 Time: 8:00 PM (no daylight savings) Long: 118 West Lat: 34 North



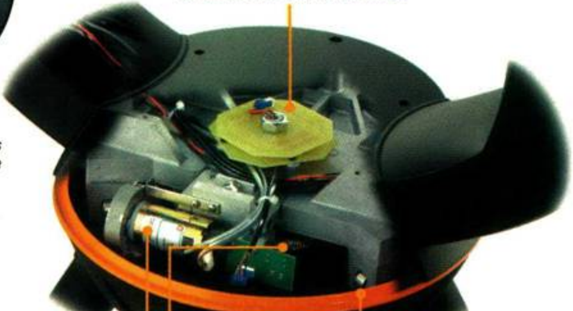
*16-channel GPS* — ***Interference free. Finderscope is positioned away from GPS antenna. Pinpoints your exact location on Earth with an unobstructed view.***

*Upgraded hand control and software features* — ***40,000 object database; new features include compass calibration, polar alignment routine, EQ AutoAlign, database filter limits, hibernate, Auto north and level, wedge align algorithm, Quick Align, user-defined slew limits.***

*Electronic compass* — ***Finds true North when used in conjunction with NexStar software.***

*Ergonomically designed fork arm with integral handles* — ***Integrated handles in fork arms designed for ease of carrying and safe and easy setup and transportation.***

*Auxiliary Ports* — ***The NexStar's auxiliary ports are located on the top of the base which rotates as the telescope turns preventing accessory cables from wrapping around fork arms.***

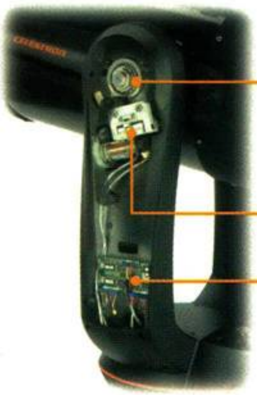


*Internal Slip Ring* — ***The NexStar's power cables will never wrap and telescope accessory cables will not get wrapped around the telescope.***

*Drive Motors* — ***Made in the U.S.A., Pittman Lo-Cog™ brush commutated DC motors offer smooth, quiet operation and long life. The motor armatures are skewed to minimize cogging which is required for low speed tracking. Windings are resin impregnated for greater reliability in incremental motion application.***

*Precision bronze gear* — ***32 pitch, 5.625" pitch diameter, 180-tooth bronze gear. Manufactured in the U.S.A. by W.M. Berg, Inc. Manufactured to AGMA Quality Class 10 standard which minimizes total composite error and backlash.***

*Unique roller bearing design* — ***Base rotates around a wide 9.5" track for maximum stability; especially important when equatorially mounting for imaging.***



*Bearing and shaft* — ***Heavy-duty preloaded tapered roller bearing on both axes.***

*Worm shaft* — ***Stainless steel worm shaft has .4375 pitch diameter and is preloaded with two ball bearings. The worm is made from a single piece of steel to minimize run-out, which is the source of periodic error.***

*Heavy-duty aluminum spring loaded worm block* — ***On both axes; minimizes backlash.***

*Motor board* — ***Each axis is controlled by its own 8-bit microcontroller.***

***To take a virtual tour of the NexStar 11GPS or to locate your nearest Authorized Celestron Dealer, please visit us at www.celestron.com***

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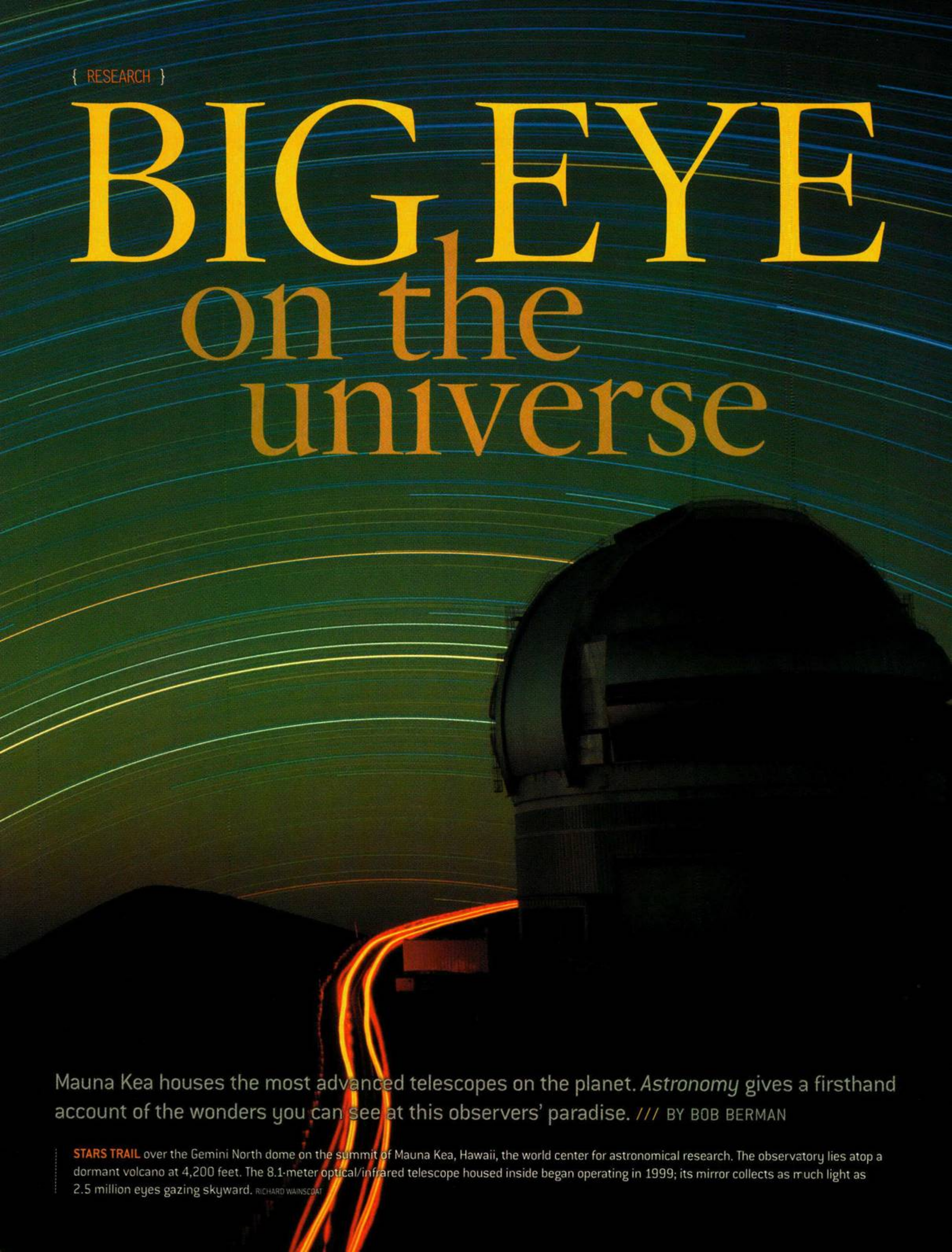


{ RESEARCH }

# BIG EYE on the universe

Mauna Kea houses the most advanced telescopes on the planet. *Astronomy* gives a firsthand account of the wonders you can see at this observers' paradise. /// BY BOB BERMAN

**STARS TRAIL** over the Gemini North dome on the summit of Mauna Kea, Hawaii, the world center for astronomical research. The observatory lies atop a dormant volcano at 4,200 feet. The 8.1-meter optical/infrared telescope housed inside began operating in 1999; its mirror collects as much light as 2.5 million eyes gazing skyward. RICHARD WAINSCOAT

Laura Kraft, Keck Observatory's new spokesperson, was struggling with the thin air when she came to meet me. After a day at the summit of Mauna Kea, the highest peak in the Hawaiian chain, her descent to the 9,300-foot visitor's center hadn't yet provided enough oxygen to clear her head. She smiled, swallowed, and finally formed words.

"Let's start at the top," she suggested a bit slurrily, gamely turning toward the four-wheel drive vehicle for the steep trip back up to the sky.

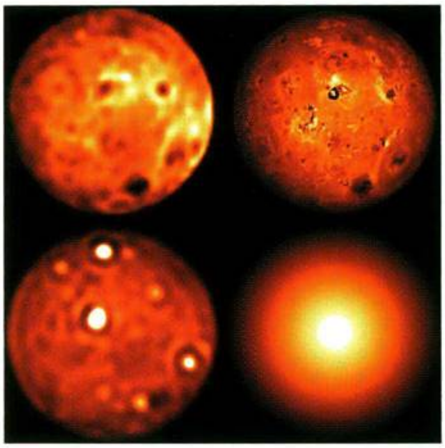
The world's largest telescopes sit at 14,000 feet in air so steady, it's legendary. Researchers turn to the Keck 1 and Keck 2 telescopes — the world's largest telescopes at 10 meters apiece — when they need brute high-tech power. Japan's Subaru, completed in 1999, is that country's flagship instrument at 8.3 meters. (*Subaru* is the Japanese name for the same Pleiades star cluster that Americans know as the Seven Sisters, and which also serves as the starry logo of Subaru cars.) One of the first telescopes to begin operating on the mountain, the Canada-France-Hawaii Telescope stands at the northern end of the summit and sports a 3.6-meter mirror that has produced some of the most stunning imagery taken from Mauna Kea. The final goliath is Gemini, which gulped its first light in 1999 using an 8.1-meter. It's owned and run by a consortium of countries: the United States, United Kingdom, Canada, Argentina, Australia, Brazil, and Chile.

Only a year ago did the twin giant Kecks first operate together as designed, combining their light in what is far and away the most powerful instrument in the known universe. "We're still young, in our toddler stage," explained Laura as we made another steep upward turn. "But already Keck does ultra-advanced research in areas like gravitational lensing — the warping of space-time. We're one of the very few telescopes that can confirm a lot of the avant-garde astronomy."

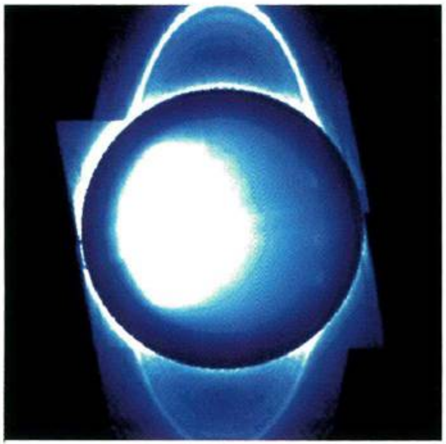
**BOB BERMAN,** *whose column* "Strange Universe" *appears monthly in the magazine, teaches astronomy at Marymount College in Tarrytown, New York. He is the author of several books, including* Strange Universe, *which will be published by Holt this fall.*

### W. M. Keck Observatory

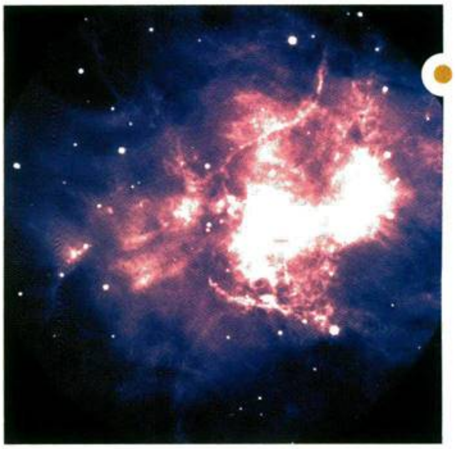
**THE TWO LARGEST TELESCOPES ON EARTH** constitute Keck I and Keck II, which together collect optical and infrared data with unprecedented clarity. ADAM CONTOS/KECK



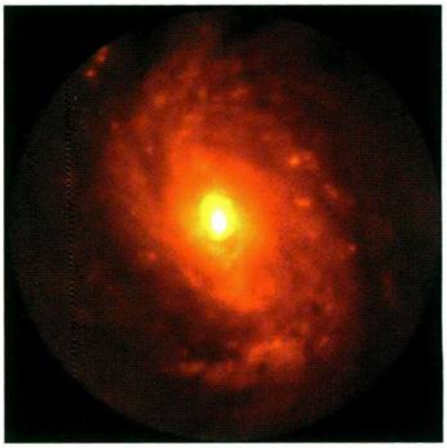
**JUPITER'S MOON IO** demonstrates the power of adaptive optics, by which software minimizes the effects of atmospheric turbulence. Counterclockwise from upper right: an image made with the Galileo spacecraft; a Keck adaptive optics image at 2.2 microns; another at 3.5 microns; without adaptive optics. KECK/CARA



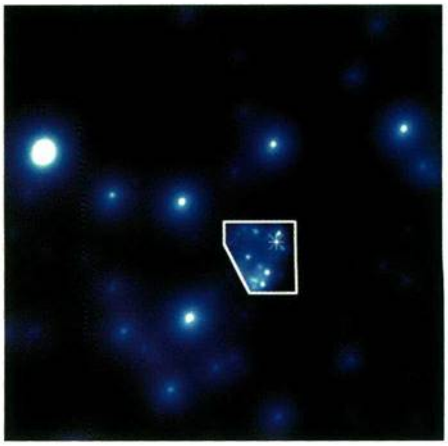
**A RAZOR-SHARP IMAGE OF URANUS**, made in the infrared with Keck II, shows the planet's methane haze layer on the south polar cap and three faint rings. IMKE DE PATER/UC BERKELEY



**THE CRAB NEBULA** is the expanding remnant of a supernova that was observed by Chinese astronomers in 1054 A.D. This 30-second snapshot was taken with Keck's LRIS imaging spectrometer. KEN CHAMBERS (U. HAWAII)/KECK

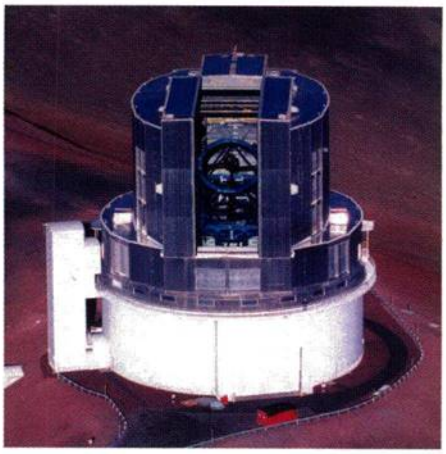


**SPIRAL GALAXY M77** glows in the infrared in this "first light" image by Keck. Researchers there discovered that M77, an active galaxy, has a compact central core (thought to be a black hole) as massive as 10 million Suns. KECK

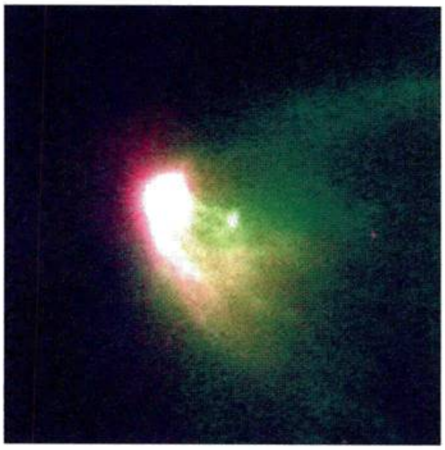


**THE CENTER OF OUR GALAXY** swarms with stars that appear to be moving around a black hole about 2.6 million times the mass of the Sun. Keck's adaptive optics system helped resolve the orbits of these stars. ANDREA GHEZ (UCLA)/KECK

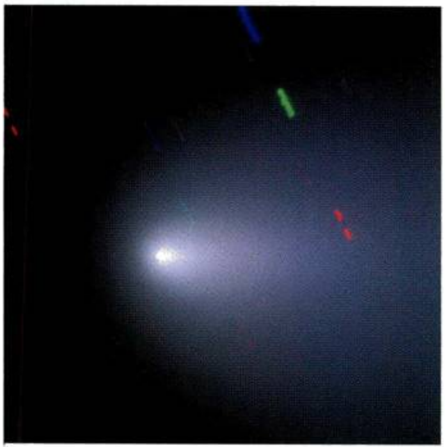
## Subaru Telescope, National Astronomical Observatory of Japan



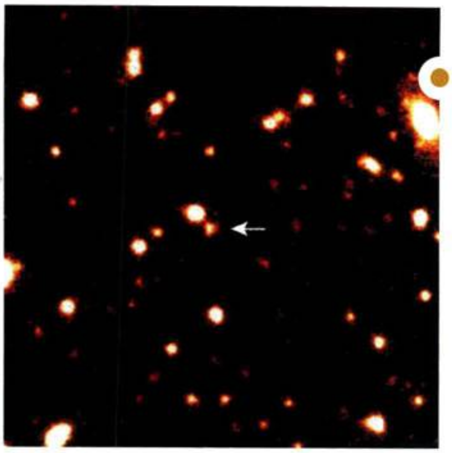
**AN 8.2-METER OPTICAL-INFRARED BEHEMOTH,** the Subaru Telescope employs an active support system for the primary mirror, a magnetic drive system for tracking, and an anti-turbulence dome design. NAOJ/SUBARU



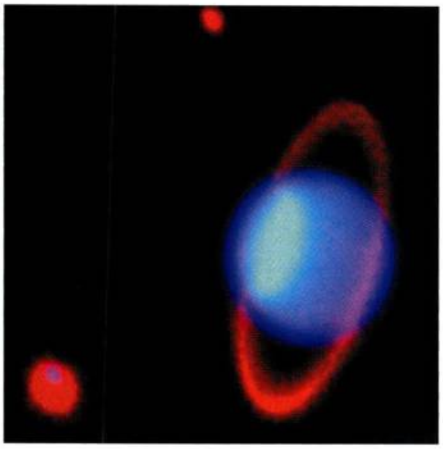
**TWIN JETS FROM A BINARY INFANT STAR** arc 140 trillion miles into the surrounding interstellar medium in an image made with Subaru's imaging spectrograph CISCO. NAOJ/SUBARU



**COMET LINEAR (C/1999 S4)** glows with gas and dust in a Subaru image taken on July 24, 2000. Tricolor stars result from the composite of three exposures — red, green, and blue — and the streaking is due to the exposure being tracked on the comet's nucleus. NAOJ/SUBARU



**AN EXPLODING GALAXY** at the edge of the visible cosmos, SDSSp J104433.04–012502.2 (arrow), hides nearly unseen in the constellation Sextans. The galaxy, a quasar, lies about 13 billion light-years away. NAOJ/SUBARU



**DISTANT URANUS AND TWO MOONS,** Miranda (top center) and Ariel (bottom left), showcase Subaru's high-resolution imagery. The near-infrared, adaptive optics shot was made in July 2001 and was filtered such that methane appears blue. NAOJ/SUBARU

**THE ANDROMEDA GALAXY (M31)** glitters with stars in this view of one of its spiral arms. Subaru's Suprime-Cam, which yields a slice of sky as large as the Full Moon, snapped the photo. NAOJ/SUBARU

But problems abound in paradise, from the practical to the philosophical. Ron Kohler, general manager of Mauna Kea Operations, waved off what I thought would have been major logistical challenges — hauling food to the staff and astronomers who live in a small housing complex at the 9,300-foot level, or keeping the facilities wired for power or cleared of snow. Supported by their own weather forecasters, Mauna Kea Operations keeps ahead of most situations, and the observatories have emergency generators. Despite the extreme conditions above more than half of Earth's atmosphere, even altitude sickness, responsible for hospitalizing people in the past, has never resulted in a visitor fatality. (Three people did die, though, during Subaru's construction.)

Ron's biggest concerns are visitors and daredevils. Incredibly enough, people with four-wheel-drive vehicles are permitted to venture to the very top and then hurl themselves off the edge on skis or boogie boards.

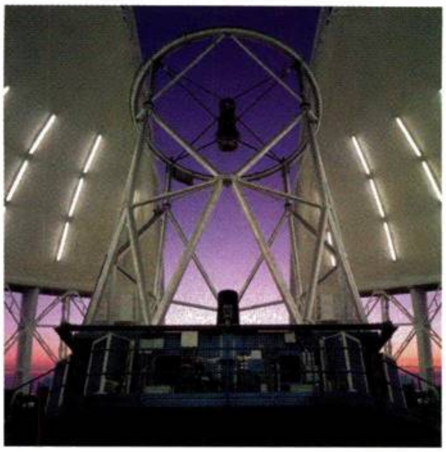
"About 20 years ago a visitor died going down in an inner tube, and around the same time another died in a car accident," said Ron. It's amazing that serious mishaps don't happen more often. Brakes easily overheat on the steep grade, and not everyone can handle the hairpin turns on the precipitous pebbly surface.

The small 10-year-old visitor center at the 9,300-foot pull-off at the end of the paved road is also one of Ron's responsibilities. Continually expanded, the center now provides literature, posters, knickknacks, and an enthusiastic, astronomy-knowledgeable staff that even provides observing equipment for visiting amateurs (see sidebar on page 45).

It's all very laid back. The potentially hazardous layout of the high-tech Mauna Kea complex would have endless rules, fences, "keep outs," and a long list of prohibited activities in much of the mainland United States. Instead, those responsible for the huge mountain reflect Hawaii's famous relaxed attitude. Skiers, astronomers, maintenance personnel,

**THE ORION NEBULA** shimmers with color in this image, whose tranquil beauty belies frenzy within. Shock waves form where fast-moving stellar jets plow into torpid gas. CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM/2002

### Gemini Observatory, Gemini North Telescope



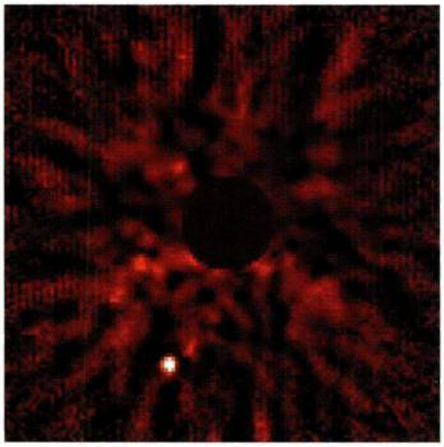
**THE AMBITIOUS GEMINI PROJECT,** a collaboration of seven nations, has assembled twin 8.1-meter telescopes, Gemini North on the summit of Mauna Kea and Gemini South on Chile's Cerro Pachon. Gemini North was dedicated in 1999; its southern brother saw first light in early 2002. GEMINI

**THE TRIFID NEBULA (M20)** in Sagittarius, a favorite target for backyard observers, churns out infant suns like a factory. GEMINI/GMOS

**THE SPIRAL GALAXY M74** glows in this composite image by Gemini North's Multi-Object Spectrograph, which gives a field of view of more than five arcminutes spread across 28 million pixels. GEMINI/GMOS

**THE CORE OF THE MILKY WAY** dazzles with stars in the first science image released from Gemini North, in 2000. GEMINI/HADG

**A BRILLIANT GIANT STAR, AFGL 2591,** lies entombed in the center of a triangular nebula in Cygnus. This infrared image made with Gemini North penetrates some of the obscuring dust that wraps around the star like a thick cocoon. The star is blowing off material as its birth winds down. GEMINI/NIRI



**THE EXTREME CLARITY OF ADAPTIVE OPTICS,** coupled with image processing, reveals a tiny brown dwarf (white circle at bottom center) beside the star 15 Sagittae. The dwarf companion lies only 0.8 arcseconds from the main star. GEMINI/UHIA

praying Hawaiian shamans — it's an eclectic group that makes the trek.

"So far we've allowed unfettered access," confirmed Bill Stormant, head of the new management agency that oversees the mountaintop's 12,000-acre, 65-year lease granted to the University of Hawaii for a dollar a year. This lease, and in fact the very presence of the observatories, has caused a bitter controversy.

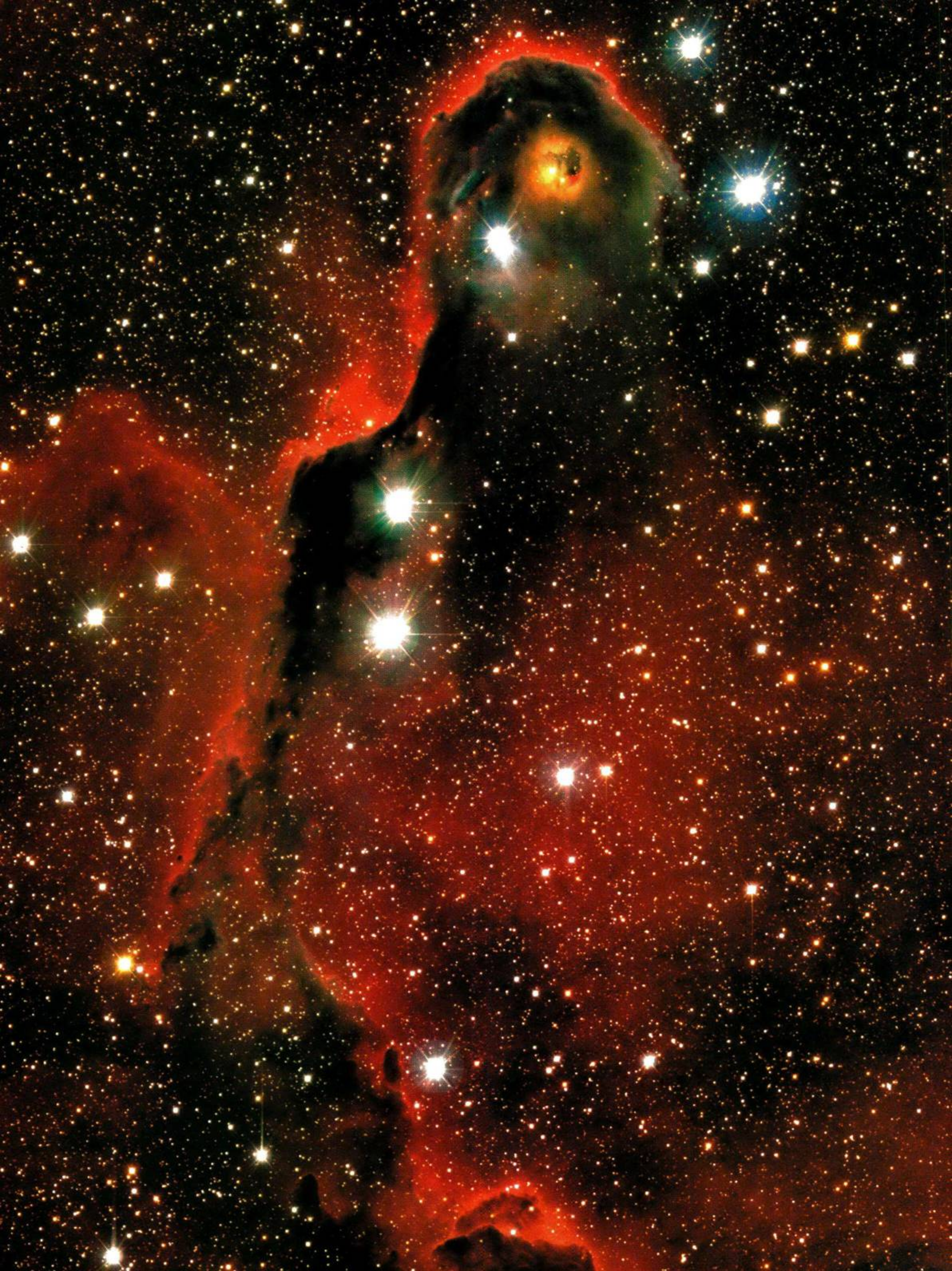
Native Hawaiian groups, who partly control the mountain in a complex arrangement, consider Mauna Kea sacred and are firmly opposed to the handful of new "outrigger" telescopes NASA has proposed building to study extrasolar planets. In fact, some Hawaiians want *all* the colossal telescopes dismantled, including Keck's twin 10-meter giants and Japan's huge Subaru instrument.

When I spoke with Kealoha Pisciotta, an activist associated with The Royal Order of Kamehameha I, among the most strident groups pushing lawsuits to block any further telescope activity, she said that even the snow from the mountain is considered "medicine," and that "astronomers had never asked the Hawaiian people whether they wanted telescopes up there."

But these problems seemed remote as Laura and I bounced our way skyward focusing on both Keck's grand role in astronomy and on the more workaday issues common to observers the world over. "Fifty percent of the nights yield useful science, while the other half is lost to weather, alignment time, and especially astronomer inefficiency," said Laura. "That last area is the one we're working on the hardest."

Laura's cognitive struggles suddenly seemed infectious: Profound light-headedness struck as I stepped out at the top into cold air. A solid layer of clouds lay beneath us, top-lit by the setting Sun to create a scene of inexpressible beauty —

**A STAR IS BORN** behind nearly every thick curtain of gas in region IC 4678 in Sagittarius. In millions of years, the stars will take separate paths into the arms of the Milky Way.
CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM/2000

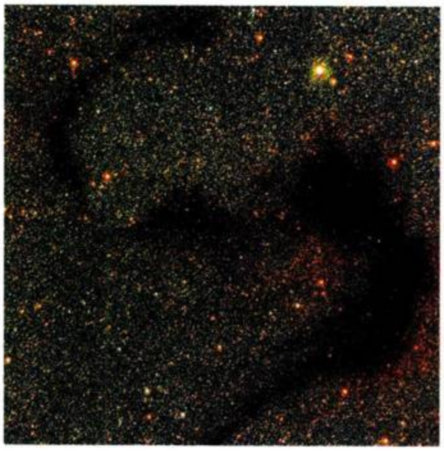


## Canada-France-Hawaii Telescope

**A PRODUCT OF 1979,** the 3.6-meter Canada-France-Hawaii Telescope is a joint venture of Canada's National Research Council, France's Centre National de la Recherche Scientifique, and the University of Hawaii. J.-C. CUILLANDRE

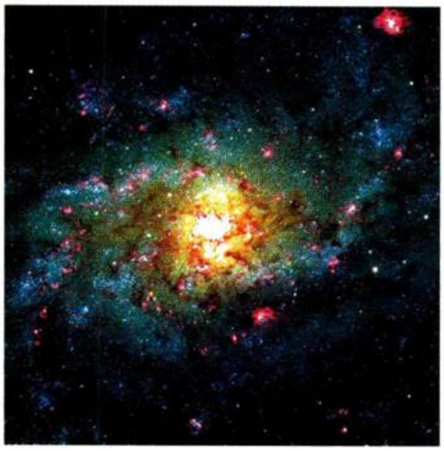
**THE VEIL NEBULA (NGC 6992/5)** in Cygnus, the exploded remains of a massive star, glows like strands of fiery rope. Such a supernova remnant will dissipate after tens of thousands of years. CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM

**THE HERCULES CLUSTER (M13),** an enormous sphere of a million old stars, lies in the Milky Way's halo about 23,000 light-years away. CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM



**A DARK NEBULA NAMED THE SNAKE** (Barnard 72), in Ophiuchus, consists of carbon particles about the size of those in cigarette smoke that block light from stars behind it. CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM

**THE WHIRLPOOL GALAXY (M51)** in Canes Venatici shows arms studded with pink regions of starbirth. The small galaxy, NGC 5195, is passing M51 like a ship in the night and drawing an arm of material away from it. CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM



**THE PINWHEEL GALAXY (M33)** in Triangulum forms an alluring but challenging object for amateur observers due to its low surface brightness. In this image, older stars look yellow and younger ones blue. CANADA-FRANCE-HAWAII TELESCOPE/J.-C. CUILLANDRE/COELUM

and desolation. The Big Island's lushness had disappeared at the vast flattened saddle of dark lava 10,000 feet below. Up here, it was like the Moon.

After unlocking several massive doors, Laura had me sign waivers holding Keck blameless in case I should drop dead from the altitude, and I struggled to concentrate while reading a page of warnings about the myriad signs of hypoxia. Some were "normal" and no cause for alarm: light-headedness, dizziness, headache. Others, like vomiting and fainting, were signals to return immediately to planet Earth below. We were operating near our limits: Mauna Kea is the world's highest manned observatory complex. The FAA requires continuous oxygen for airplane passengers at this altitude.

A long, echoing corridor, along which doors lead off to complexes of offices and labs, separates the two Kecks. One workshop sparkled with a pair of million-dollar hexagonal mirror segments suspended for recoating, part of the ongoing keep-it-all-perfect program.

We walked into a pitch-black elevator that took us up to the catwalks surrounding one of the monster telescopes. Using her walkie-talkie, Laura asked the control room to open the dome and slew the colossal instrument around. Suddenly, different components began to move in various bewildering directions. The dome's interior that I'd been leaning against suddenly rotated one way, the telescope itself moved at a different speed, and the catwalk below our feet rumbled and seemed to move at yet another. It was impossible to know whether my own body was stationary or in motion.

I gazed at the adaptive optics room and the cables and pistons that make parts of each mirror deform twice per second. These obey 500-times-per-second measurements taken from a cloud pierced by a laser 40 miles above the mountain. This sci-fi-like artificial star lets the system continually appraise and compensate for the changing seeing. "It's new," Laura boasted, "and it sharpens images dramatically."

"But only in the infrared," I added, unable to resist showing off. Visual wavelengths, being shorter and more detailed, would require far more measurements and actuators, beyond the capability of current technology for very large scopes.

Laura walked us through Keck's control room. One illuminated indicator was particularly intriguing. Giant red LED numbers glowed "13.37" under the heading AIRMASS. This wonderful indicator, which would be handy for every amateur, reveals how many atmospheric thicknesses the light from celestial objects must penetrate. Stars at the zenith pass through one atmosphere, while targets sitting on the horizon, where the telescope was currently pointed, must pass through 13 times more air, water vapor, and whatever crud is floating around up there. No wonder the Moon often looks orange when rising, why it's generally safe to stare at a setting Sun, and why 5th magnitude stars are invisible when low.

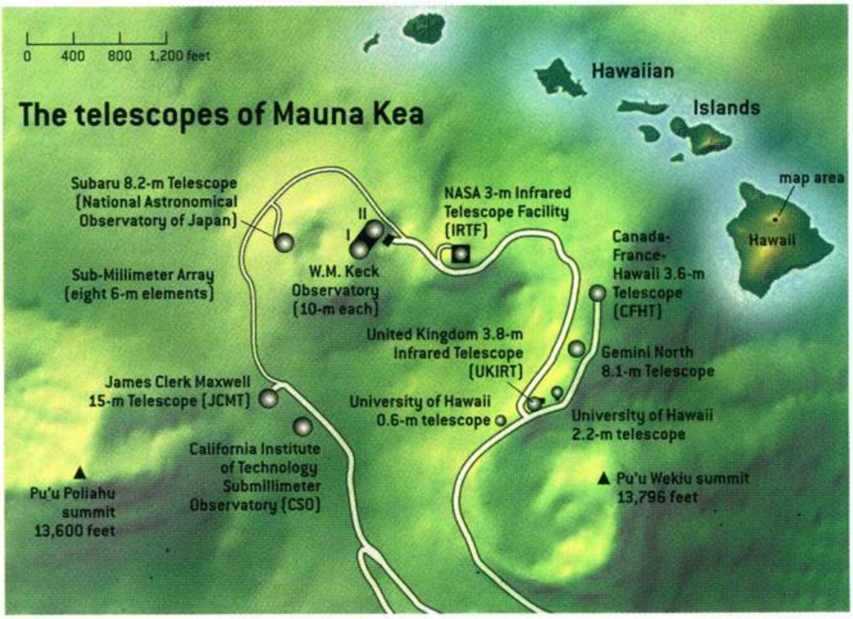
As we walked back through the empty corridor, the subject of the native Hawaiian movement to stop all telescope construction came up again. I knew that several groups had joined forces in a lawsuit, led by the Office of Hawaiian Affairs. Part of the motivation, many believe, is residual anger at the White Man's annexation of the islands in the first place, which some activists still contend is illegal. Meanwhile, a countersuit has been filed, arguing that the Office of Hawaiian Affairs, as a government agency, cannot take sides in what is essentially an ethnic battle.

At first Laura balked. "It's in litigation. I'm not allowed to talk about it." But further prodding, combined perhaps with altitude inebriation, made her struggle between politically correct neutrality and strong personal opinions. The latter won out, and Keck's spokesperson expressed feelings so impassioned and eloquent, they were almost poetic.

"We are honoring Mauna Kea by doing what we do," she finally said, fire in her eyes. "These observatories are our temples." She paused. "The truth is, we see Keck as a gift — and our goal is to benefit all of humanity."

She also spoke of the legitimate sensitivities and spiritual passions of the native Hawaiians. "Nonetheless," she said, almost to herself as we stepped out into the cold windy night for the long ride down, "before there was Mauna Kea, there were the stars." ■

## /// STARGAZING ON MAUNA KEA


0 400 800 1,200 feet
The telescopes of Mauna Kea
Hawaiian Islands
map area
Hawaii
Subaru 8.2-m Telescope (National Astronomical Observatory of Japan)
Sub-Millimeter Array (eight 6-m elements)
II
I
W.M. Keck Observatory (10-m each)
NASA 3-m Infrared Telescope Facility (IRTF)
Canada-France-Hawaii 3.6-m Telescope (CFHT)
United Kingdom 3.8-m Infrared Telescope (UKIRT)
Gemini North 8.1-m Telescope
James Clerk Maxwell 15-m Telescope (JCMT)
University of Hawaii 0.6-m telescope
University of Hawaii 2.2-m telescope
California Institute of Technology Submillimeter Observatory (CSO)
Pu'u Poliahu summit 13,600 feet
Pu'u Wekiu summit 13,796 feet

ASTRONOMY: ROEN KELLY

**You'd think the legendary Mauna Kea** mountain, home to the world's largest telescopes, would be off-limits to amateurs. Not so. In fact, it's never been. Hawaiian astronomy groups have driven to the 9,300-foot turn-off to set up telescopes at least since the 1970s, long before the Kecks or even a visitor center existed.

And visiting has gotten even easier. Two decades ago a local amateur group fought successfully to get permanent concrete piers installed for visitors' scopes. The ever-growing information center is now open every day. Thanks to generous donations, serious telescopes — a professional-grade 16-inch Meade, a 6-inch Dobsonian, and 14-inch and 11-inch Celestrons — are wheeled out nightly for anyone to use. Even before the Sun sets, a 4-inch clock-driven Televue refractor with a Coronado H-alpha filter takes advantage of the thin air for exquisite solar views.

But if you don't know what an H-alpha filter is, not to worry. "Most of the people who come up here don't know the first thing about astronomy," says Eric Rowe, a member of the Mauna Kea management team. "We show them a few planets and deep-space objects and they're always impressed. Many have never even looked through a telescope before." Serious amateurs make the trek too, a three- to four-hour roundtrip drive from Hilo or the Kona coast.

Almost everyone feels the 9,300-foot altitude, especially after ascending directly from sea level. However, it is far less debilitating than the dramatic, dizzying, hypoxic effects at the 14,000-foot summit, off-limits to visitors after dark.

Most of the few hundred daily visitors to the center are gone by 8:30 P.M. But native Hawaiian Howard Yamasaki, a dedicated, knowledgeable amateur who has come up hundreds of times during the past quarter-century advises, "Serious observers need to stay past midnight." Mauna Kea's almost mythical "perfect seeing" requires the Sun's intense heating by day to dissipate the misty clouds. According to Yamasaki, this happens about five hours after sunset.

At 10 P.M. the center wheels in its heavy telescopes, empties its leftover coffee, and closes for the night. Then you're on your own. Hang out all night, sleep in your car — nobody cares. The entire Big Island uses low-pressure sodium lights with shielded fixtures, so the sky will be inky dark. In those exquisite conditions, arriving when the Moon is bright would be almost criminal.

What's the most impressive deep-space object visible from Mauna Kea? The astro-savvy staff, director, and volunteers who operate the telescopes unanimously agree. It's the great globular cluster Omega Centauri, whose season is February through July. But if you want to arrive when tourists are at a minimum and the weather is still great, come between September 7 and November 10. No season, however, is bad. Any time you make the pilgrimage, Mauna Kea will be waiting with something special. — B. B.

# The turbulent world of compact galaxy groups

No longer astronomy's freaks, compact groups of galaxies have become laboratories for studying how galaxies evolve, interact, and grow. /// BY MARCIA BARTUSIAK

In 1864, atop France's Plateau Longchamp near the Mediterranean Sea, the Marseille Observatory installed the largest reflecting telescope then in existence. Designed by Léon Foucault (of pendulum fame), the reflector was a technological marvel. It was the first large telescope with a silver-on-glass mirror, which allowed observers to gather far more light than possible with polished-metal mirrors. Eighty centimeters (31 inches) wide, the silvered mirror helped the observatory's director, Edouard Stephan, discover a host of faint nebulae never before charted.

Stephan's most captivating find came in 1877. While exploring the northwest corner of the autumn constellation Pegasus, he noticed an unusual collection of five nebulae huddling close like a scout troop around a campfire on a cold night. In honor of its discoverer, this striking assembly of "nebulae" (actually galaxies) is called Stephan's Quintet. With brightnesses ranging from 13th to 15th magnitude, the group is a favorite target for amateur astronomers with large telescopes. Film buffs may also know these five galaxies from the Christmas holiday classic *It's a Wonderful Life*. The movie opens with an image of the quintet depicting angels engaged in conversation.

**THE WHIRLING HEART OF STEPHAN'S QUINTET,** the first compact galaxy group ever found, reveals a violent past. Millions of years ago, a quintet member not visible in this image barreled past these galaxies and ripped a 100,000 light-year-long trail of gas from NGC 7319 (upper right). Compact groups are defined by a tightly knit band of a few galaxies.

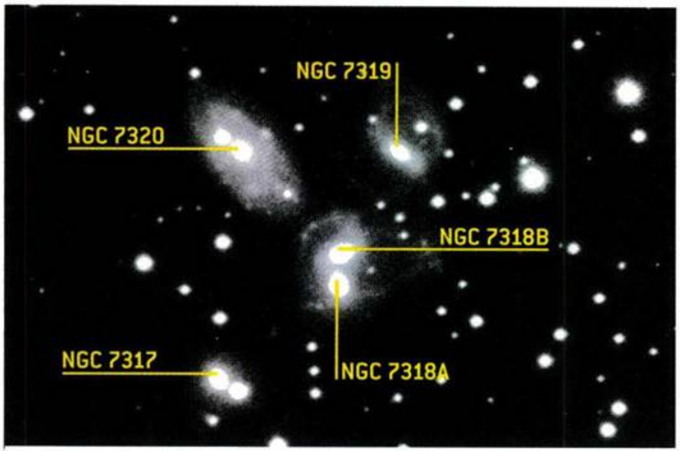
NASA, JAYANNE ENGLISH (UNIVERSITY OF MANITOBA), SALLY HUNSBERGER (PENNSYLVANIA STATE UNIVERSITY), ZOLT LEVAY (SPACE TELESCOPE SCIENCE INSTITUTE), SARAH GALLAGHER (PENNSYLVANIA STATE UNIVERSITY), AND JANE CHARLTON (PENNSYLVANIA STATE UNIVERSITY)

## Not your ordinary cluster

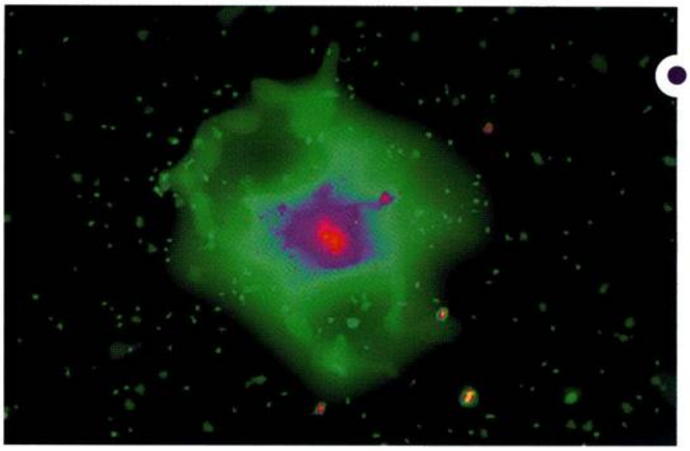
Cosmologists have long known that galaxies form loose groups, clusters, and superclusters that weave a bubbly, filamentary network throughout the universe. But groups like Stephan's Quintet are distinctive. They typically consist of just four or five galaxies gathered closely in a region where galaxies are usually sparse. According to Jane Charlton, an astronomer at Pennsylvania State University, a compact group is defined as having no other galaxies around it for at least three times the angular diameter of the group. In normal clusters, there's no such clear-cut border. Like a handful of skyscrapers rising from a rural cornfield, a compact group of galaxies resembles the core of a rich cluster — minus the cluster.

Such collections are rare. After Stephan's Quintet, the next one was not discovered until 1948, when Carl Seyfert of Vanderbilt University noticed six bright objects crowded together on a deep-field photograph. Although recent research has shown that only four galaxies are actually bound to the group, Seyfert's Sextet was one of the densest compact groups known, with its six members apparently squeezed into two arcminutes, barely 1/15 the width of the Moon.

A few decades ago, only one or two papers were published each year on compact groups; today, a couple dozen appear annually. While normal clusters may host the same number of galactic interactions and mergers, which occurred quite frequently in the first few billion years after the Big Bang (when the universe was smaller and denser), compact groups are easier to study because of their size. By examining bursts of star formation and galactic activity within compact groups,



**THE FIVE GALAXIES THAT MAKE UP STEPHAN'S QUINTET** are not obvious at first glance. Members include NGC 7317, NGC 7318A and B, and NGC 7319. Surprisingly, NGC 7320 is not a true group member, while galaxy NGC 7320C, lying outside of this image, is. Backyard astronomers can glimpse the group in Pegasus glowing dimly at magnitude 14. CHUCK VAUGHN



**X-RAY EMISSION** from compact groups lends credence to their status as gravitationally bound objects. The gas between galaxies in a cluster often heats to millions of degrees, radiating x rays that can be detected by observatories such as Chandra, which took this false-color image of HCG 62. Black and green denote low x-ray intensities, red and purple high. J. VRTILEK ET AL./CFA/NASA

astronomers have a grand opportunity to see how galaxies may have evolved through the eons.

"We can learn how galaxies interact and how fuel can be funneled into an active galactic nucleus," says Paul Hickson, an astrophysicist at the University of British Columbia. "It will help us answer why some galaxies have active black holes in their centers and others don't."

## Discordant redshifts

Astronomers began to look closer at these uncommon galaxy groups a generation ago, thanks to a rancorous controversy. In the early 1960s, redshifts were obtained for members of Stephan's Quintet and Seyfert's Sextet. (Such observations determine the displacement of a galaxy's spectral lines toward the red, a measurement that indicates how fast a galaxy is receding as the cosmos balloons outward. It also gives the galaxy's distance.) In both groups, one galaxy had a very different redshift from the rest of the group. Another "discordant redshift" was found among a remarkable chain of five galaxies called VV 172.

At first it seemed unlikely that a foreground or background galaxy would so often appear to lie near a rare compact group. And for years this perception gave ammunition to a camp (led by maverick astronomer Halton Arp) that argued redshifts were not necessarily due to an expanding universe, but to some yet-undiscovered physics.

Misfit redshifts weren't the only puzzle. The galaxies within each compact collection all had high velocities relative to one another, suggesting they were in the process of coming apart. Astronomers now realize that dark, invisible matter was enveloping the systems and acting as gravitational glue to keep the galaxies bound together despite their speedy motions, which were themselves a result of gravitational interactions.

The redshift debate has also died down. More recent statistical studies that use larger samples of compact groups concluded the discordant galaxies are simply fortuitous, line-of-sight projections. They really are unconnected to the compact groups they appear to lie within.

"Our results confirm that projection alone can account for the high incidence of discordant redshifts," reported Hickson and Angela Iovino of Italy's Brera Observatory in 1997.

## Surveying the field

The study of compact groups took a decisive step forward in 1982 when Paul Hickson compiled a catalog of these unusual systems. Up until then, only a dozen or so were known, mostly accidental finds. To understand the properties of these special objects, Hickson knew that astronomers needed a larger sample, selected systematically. He chose specific membership criteria: a certain number in the group (four or more); densely packed (separated by just a few galactic widths); and fairly isolated (no other galaxies within a certain distance). To hunt for them, he spent months poring over prints from the original Palomar Observatory Sky Survey conducted in the 1950s, about a thousand plates in all.

"I used a big, long plastic ruler, set it down on the plate, and then scanned along with a magnifying glass," he recalls. "Then I'd move the ruler down and scan another line, continuing this procedure down the plate."

In the end he found exactly 100 compact groups of galaxies, known by the designation HCG, for Hickson Compact Group. (Stephan's Quintet, for example, is HCG 92 and Seyfert's Sextet is HCG 79.) Through the 1980s, Hickson and his graduate students carried out extensive photometry and spectroscopy on each group.

With such a large dataset available at last, other astronomers were soon attracted to these systems as well. Hickson groups have now been studied with infrared, radio, and x-ray telescopes. New digital scans of the sky, as well as redshift surveys, are revealing new groups yearly. As the list of compact groups has swelled, a few members of the Hickson catalog have also been removed. Some have proven to be chance projections of galaxies at varying distances; a few turned out to be the cores of

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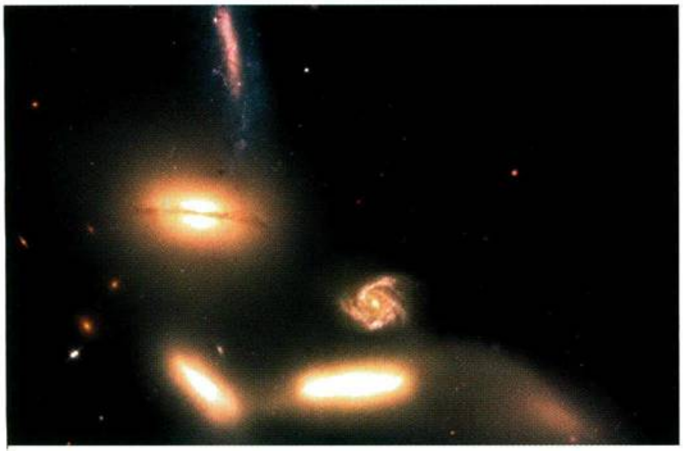
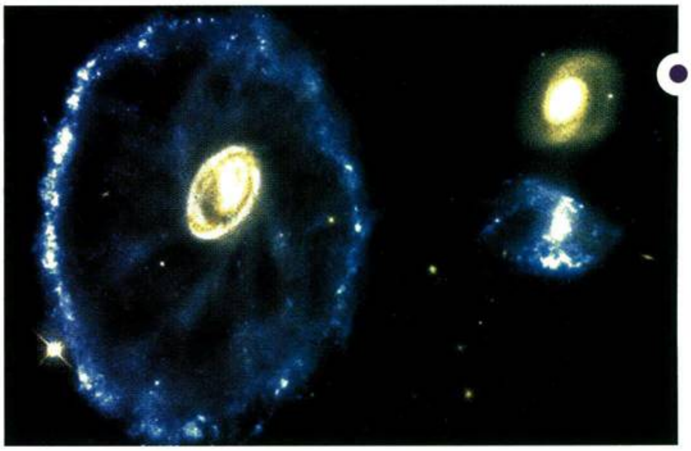
**Marcia Bartusiak,** a member of *Astronomy*'s Board of Advisors, is a science writer based in Massachusetts. Her award-winning book, *Einstein's Unfinished Symphony*, was published in paperback this February.



**SEYFERT'S SEXTET,** in the constellation Serpens, is actually a misnomer. The small face-on spiral at center is about five times farther away than other group members, and the sixth "galaxy" (lower right) is simply a trail of stars ripped from another galaxy. NASA, J. ENGLISH (U. MANITOBA), S. HUNSBERGER, S. ZONAK, J. CHARLTON, S. GALLAGHER (PSU), AND L. FRATTARE (STSCI)



**CELESTIAL FIREWORKS** hang in the sky in the form of the Cartwheel Galaxy, whose ringed structure is a result of a head-on collision a few hundred million years ago with one of the two galaxies beside it. Such forceful collisions are thought to occur often in compact galaxy groups, seeding millions or billions of new stars in the process. K. BORNE (STSCI)/NASA

larger clusters. "In one case I even mistakenly identified a star as a galaxy," says Hickson.

A few astronomers wondered whether these groups were merely filaments in the universe's bubbly large-scale structure as seen from one end, looking straight into the filament. Indeed some may be, but the majority appear bound together. Almost half of the HCGs, for example, show signs of ongoing interactions between members: Galaxy shapes are distorted, galactic centers are brightened (a sign that gas is flowing in and fueling an active nucleus), and sweeping trails of stars attest to past galactic encounters. Moreover, compact groups appear to be deficient in neutral hydrogen, which was likely stripped away by frequent gravitational interactions. Galaxies in a chance alignment would not share such similar properties.

Compact groups may dissolve like aspirin in water, evolving slowly from spirals into a single hypergalaxy via persistent tidal stripping.

## Living fossils

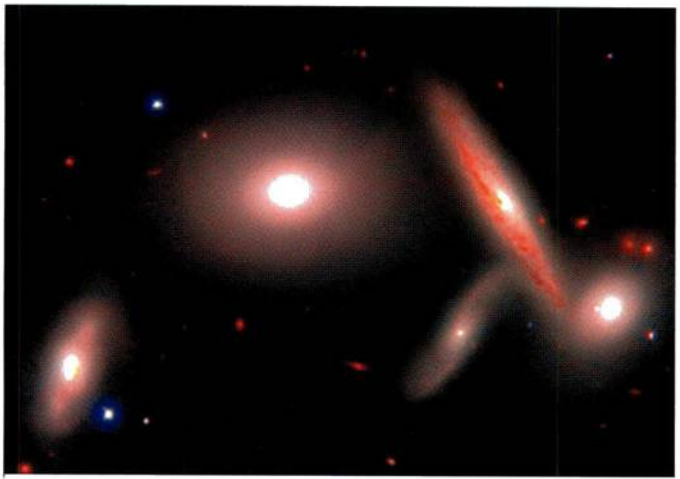
How can such dense groups form in the first place? The latest evidence suggests that close-knit systems can form as transient associations within looser groupings of galaxies, perhaps inside particularly dense clumps of dark matter. Cosmologists looking at the big picture suspect that if this is true, then such groups offer further proof that the universe's matter-energy content approaches or equals so-called "critical density." This is their term for the knife-edge balance between a cosmos that's completely open (and expanding forever) or closed (wherein the expansion someday stops and reverses toward a cosmic collision, or Big Crunch). Such tight groupings could not form gravitationally if the universe were less dense.

But one mystery remains — how long can compact groups live? Early on, in 1977, Hickson and colleagues Douglas Richstone and Edwin Turner published a paper noting that the lifetime of these compact groups should be "disturbingly short." "We recognized there was a severe merging instability," says Hickson. Gravity would draw the close galaxies together quickly to form one large galaxy.

In the 1980s, astronomer Joshua Barnes, now at the University of Hawaii, carried out computer simulations of interacting spiral galaxies and reached the same conclusion. Dense groups did not last very long in his models — just a fraction of the universe's age. In his simulations, the galaxies merged to form one elliptical galaxy in a billion years or less. This may explain the occasional giant elliptical seen isolated in space, the result of a compact group that eventually coalesced completely. Ellipticals are usually found in the cores of clusters.

Trevor Ponman of the University of Birmingham in Great Britain and six colleagues identified a possible fossil compact group using the ROSAT x-ray telescope. They discovered a large elliptical galaxy some 2 billion light-years distant whose x-ray luminosity and properties closely resembled that of a compact group. It was "similar to the giant elliptical galaxies at the centers of clusters, yet . . . apparently isolated," they reported in 1994. "The most natural explanation . . . is that it is the merged remains of the galaxies which previously constituted the group."

Yet if compact groups merge quickly, why then do any still exist? Some astrophysicists suggest that compact groups could be continuing to form as subsystems within larger groups. "From some lines of sight," points out Barnes, "our own Local Group of galaxies — the Milky Way, Andromeda, and Triangulum — probably looks like a compact group. But we're only now starting the process of gravitationally collapsing." A group might also be refreshed and reinvigorated by the periodic infall of new galaxies from their surroundings.



**HCG 40'S HIGH-SPEED GALAXIES** might have merged long ago were it not for the dark matter that envelops and preserves them, astronomers believe. In computer simulations, dark matter and angular momentum stave off mergers long enough to explain the number of compact groups we see today. CISCO, SUBARU TELESCOPE, NAOJ

**THE GALAXIES IN HCG 87,** short for Hickson Compact Group 87, revolve around a common center every 100 million years. Insight into these systems and their role in galactic evolution and dynamics has grown by leaps and bounds since 1982, when astronomer Paul Hickson compiled a catalog of 100 such groups. AURA/STSCI/NASA

Other astronomers wonder if the compact groups seen today survive longer and are actually much older than assumed. Members of this camp contend we don't see enough fossils if swift mergers have gone on since the beginning. To test this, researchers at the Marseille Observatory — where Stephan discovered the quintet — recently conducted new computer simulations of mergers within compact groups. When they adopted the simplest initial conditions, the Marseille team ended up, like Barnes, with rapid mergers. But they found they could avoid this fate if they added some angular momentum (spin) to the group and an extensive halo of dark matter enveloping the entire group. The more massive the halo, the slower the merger rate. In this way, a compact group forged in the early universe could still be around. The dark matter serves as a buffer to slow down — or even hold off — a merger.

"They're like flies caught in molasses," says Jack Sulentic, an astronomer at the University of Alabama who worked with Arp as a post-doc during the height of the redshift controversy and leans toward this view. "Seyfert's Sextet is an old group, yet we still see its individual galaxies. This suggests compact groups do not merge violently and swiftly but dissolve like aspirin in water. There's a slow evolution from spirals into a single hypergalaxy via persistent tidal stripping."

## Local disturbances

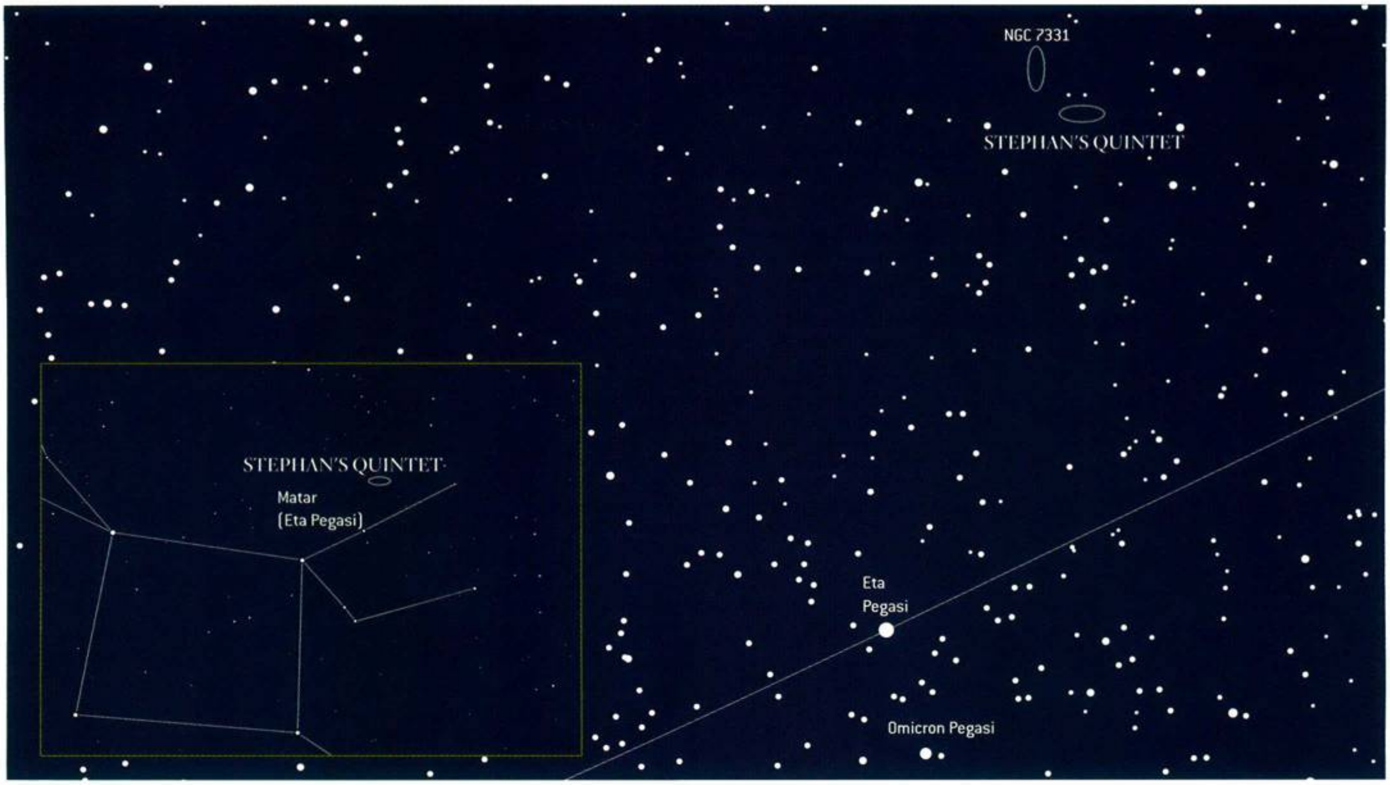
Along with the statistical studies encompassing all known compact groups, astronomers are also zooming in on individual groups to understand their dynamics. Two years ago Sarah Gallagher, Jane Charlton, and Sally Hunsberger from Pennsylvania State University trained the Hubble Space Telescope's keen eye on Stephan's Quintet and revealed breathtaking details within that special environment.

They found galactic distortions, long trains of stars sweeping outward from past interactions, and bursts of star formation. Hubble's high resolution confirmed that NGC 7320, the large spiral galaxy at the southern edge of the quintet, is not a true member of the system but a foreground galaxy situated some 35 million light-years away. The other quintet members — NGC 7317, NGC 7318A and B, and NGC 7319 — lie nearly eight times farther out, at a distance of 270 million light-years.

Just 250 million years ago, the quintet captured the spiral galaxy NGC 7320C (now seen off to the east) as it sprinted through the group, ripping out a wispy trail of gas and stars in its wake. The tidal disruptions of this passage triggered new stars to form. Evidence for an even older tail, aged 750 million years, suggests this might have been the second time NGC 7320C sped through the group. Whoever the culprit was, NGC 7320C is now a member of the quintet and will return again many millions of years from now, yanked back like a ball on an elastic string. In fact, some tidal disturbances are occurring right now. As NGC 7318B races through the quintet at more than 800 kilometers (500 miles) per second, it's wreaking similar havoc on NGC 7318A.

"That's an amazing velocity for a group galaxy," says Sulentic. "They usually move at 100 to 200 kilometers per second. It's heating the gas within the group to a million degrees and creating a tremendous shock wave, one of the largest we've ever seen — [as big as] a significant fraction of the diameter of the Milky Way. And all this is happening now. We've caught it 'in flagrante delicto'." Sulentic recently published a multiwavelength study of the quintet with colleagues from Mexico, Spain, Italy, and Germany. In a few million years, he says, the quintet will begin to cool down.

Such encounters may be another reason that certain compact groups condense more slowly than expected. Galaxies periodically passing through can transfer enough energy to the group to prevent members from merging into one giant galaxy. In time, NGC 7318B will shoot completely through the group and leave the system entirely — it's moving too energetically to stop. Its collision began some 20 million years ago, but star clusters are still being born as a result. Like a series of linked fireworks, the explosive death of one generation of stars can trigger the birth of the next, and so on down the line. "So much gas gets stripped out of the galaxies during these encounters and



**LOOK FOR STEPHAN'S QUINTET** just above the Great Square of Pegasus, which rises in the wee hours of the morning this month. JAY SMITH

thrown into intergalactic space," notes Jane Charlton, "that stars even form in those regions, outside the galaxies."

"Stephan's Quintet is a valuable laboratory," adds Sulentic. "There are many compact groups, but not all are active at the same moment. So we're lucky to see one in action." The last time something like this happened nearby may have been 300 to 400 million years ago, when an intruder punched completely through a spiral galaxy, creating the famous Cartwheel Galaxy, an immense ring-like structure 100,000 light-years wide.

## Out of the debris

Charlton and her colleagues continue to sift through the Hubble data, focusing on the dwarf galaxies often sprinkled throughout compact groups. In recent years evidence has been growing that dwarf galaxies can form in the tidal debris left over after two galaxies interact. The Hubble image of Stephan's Quintet displays this very clearly. According to Pennsylvania State University astronomers, some of the material in the quintet's tidal debris has now created 20 or so dwarf galaxies.

The big question, says Penn State astronomer Christopher Palma, is whether the dwarf galaxies are massive enough to keep their stars from drifting apart. Radio observations of neutral hydrogen in Stephan's Quintet from the Very Large Array suggest many might be, depending on their provenance. The observations revealed another tidal tail, not visible in the optical. It stretches due north from the other tails and is likely the remnant of another ancient encounter.

"In searching for dwarf galaxies within Stephan's Quintet, we found dwarfs lined up with this tail of hydrogen, and this is important," says Palma. By being embedded in the gas, which provides additional gravitational glue, they're likely to survive, he argues. And that could mean that a good number of dwarf galaxies in the present-day universe were created in just this way, out of the debris of galactic interactions and mergers during the universe's infancy.

The quintet's image could be a snapshot of events that occurred regularly in the early universe, when galaxies were first forming. Palma estimates that up to a third of dwarf galaxies might have originated as tidal debris, although he stresses this is still speculation. The Penn State team hopes to use the Hubble Space Telescope again to look at 20 additional compact groups and examine dwarf galaxy populations more broadly.

Aside from serving as a special laboratory for observing interactions and mergers, compact groups of galaxies fulfill another service — sheer cosmic pleasure. Take HCG 87. In 1999, members of the public visiting the HST website voted to have Hubble's wide field camera take a special picture of this particular group for its Heritage Image Gallery. Voters were not disappointed. By combining the images taken separately through four different color filters — blue, green, red, and infrared — Hubble astronomers created a full-color portrait of HCG 87. This celestial family of three spirals and one elliptical offers a stunning view of a universe in miniature.

Even though Jane Charlton had a hand in obtaining that vivid image, HCG 87 is not her favorite Hickson compact group. That title goes to the first such group ever found, the sparkling collection of star systems known as Stephan's Quintet. "Not only because it was the first Hubble time I ever got," she says, "but also because of its connection to the movie *It's a Wonderful Life*. When I was young, I always wondered what the galaxies in that movie were. Now, it's a nice way to break the ice with the public when I talk about compact groups." ■

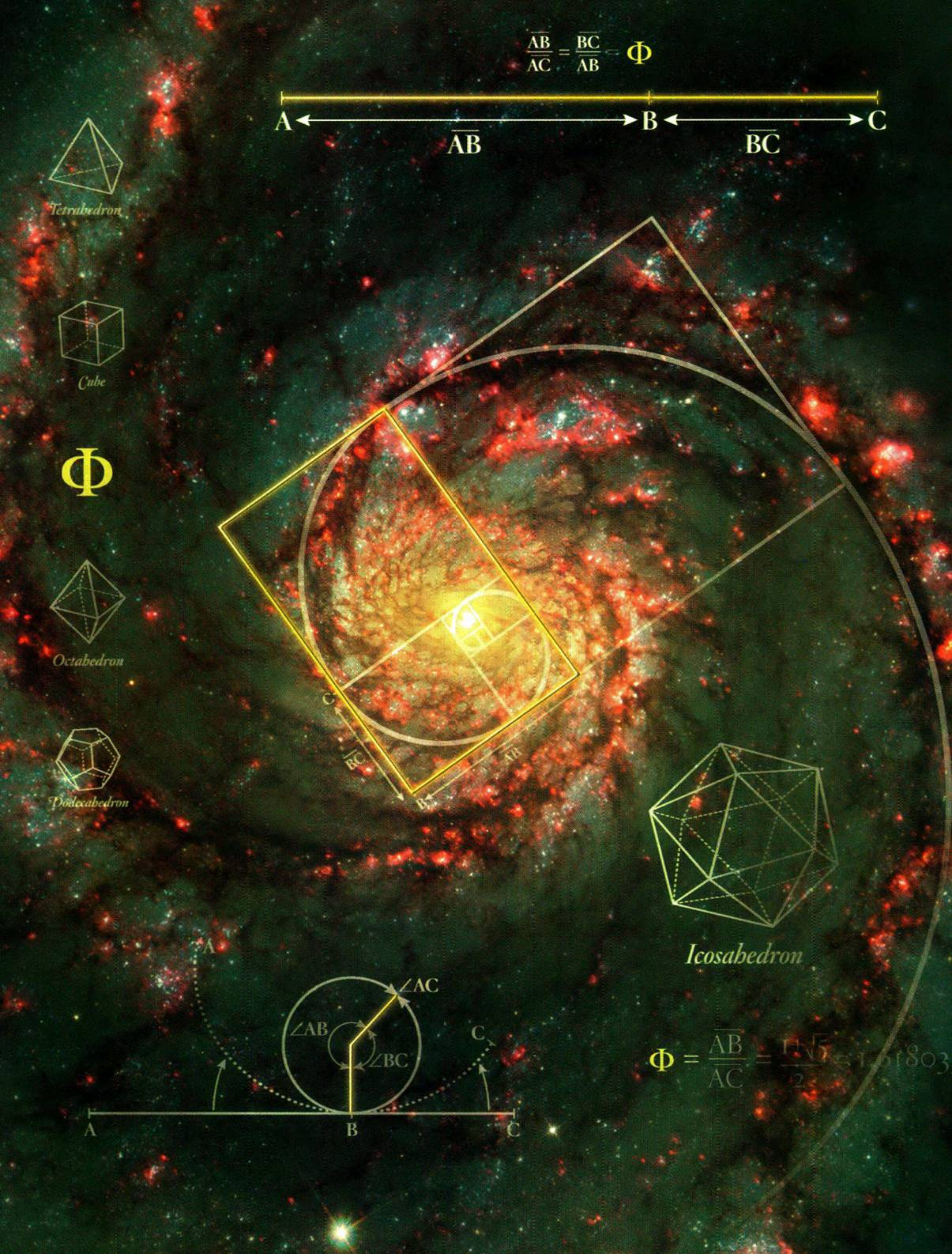
# Searching for the golden ratio

A geometric proportion discovered in antiquity turns up in sculpture, botany, planetary orbits, and in the thermodynamics of black holes. /// BY MARIO LIVIO

While déjà vù is not a term generally applied to mathematics, certain numbers — angles, ratios, constants — have a way of cropping up with haunting regularity. Many people are familiar with the number π (pi, 3.1415...). This symbol-number, derived from the ratio of a circle's diameter to its circumference (d ÷ c – π), reappears throughout geometry and physics. This Greek letter is not alone, however, in its permeation of math and science. A second symbol, Φ (phi), has laid claim to its own number and its own amazing set of places in the natural world. This is the story of Φ.

The golden ratio Φ shapes the world around us. The spectacular fact that this number shows up repeatedly through nature was recognized in antiquity, when Euclid of Alexandria stumbled on its significance. Generations of successors in unveiling the mysteries of the universe continued to confront the meaning of Φ, from Ptolemy and Kepler to mathematicians Luca Pacioli and Martin Ohm. The most stunning aspect of Φ, however, is its connection to the far-more sophisticated world of 21st-century astrophysics. We can follow the historical story of the golden ratio all the way to our own day, in which we find it intertwined with the physics of quasicrystals and rotating black holes.

**M51'S SPIRAL ARMS** reflect the golden rectangle, in which the ratio of the length AB to the height BC is equal to Φ. Make a square inside this rectangle (a) and then draw a square outside it (b). The new rectangles are also golden rectangles, and the ratio between the squares is the golden ratio. The golden ratio is key to many geometric shapes (left and right). Bending a line into a circle (bottom left) reveals the golden ratio hiding in the angles that trace the circle's segments. HUBBLE HERITAGE TEAM

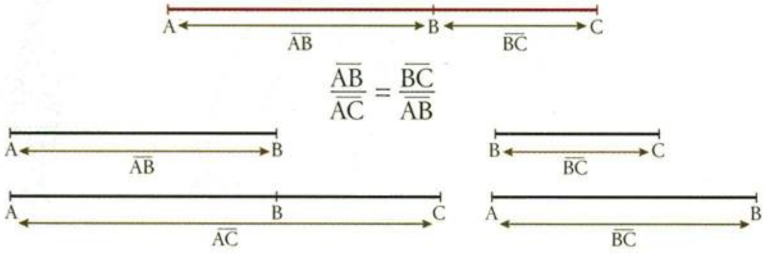

$\frac{\overline{AB}}{\overline{AC}} = \frac{\overline{BC}}{\overline{AB}} = \Phi$
A
B
C
$\overline{AB}$
$\overline{BC}$
Tetrahedron
Cube
Φ
Octahedron
Dodecahedron
C
$\overline{BC}$
$\overline{AB}$
B
Icosahedron
A
∠AC
∠AB
∠BC
C
A
B
C
$\Phi = \frac{\overline{AB}}{\overline{AC}} = \frac{1+\sqrt{5}}{2} \approx 1.61803$

/// RATIOS AND LINES

**IN THE GOLDEN LINE,** Euclid proposed the possibility of dividing a line into two segments such that the ratio of the whole line to the larger segment is the same as the ratio between the larger and the smaller segments.

$$\overline{AB}+\overline{BC}=\overline{AC}$$

$$\frac{\overline{AB}}{\overline{AC}}=\frac{\overline{BC}}{\overline{AB}}$$



## In the beginning

The story of the golden ratio begins with Ptolemy I, successor to Alexander the Great, who rose to power in 323 B.C. Among his first great acts was the establishment of a school known as the "Museum" in Alexandria, Egypt. Founded around 300 B.C., this ancient university included among its teachers the father of formal deductive geometry — Euclid.

In his "best-selling" book, *Elements*, Euclid defined geometry and number theory. Until the 20th century, no book besides the Bible had sold more copies than this first great mathematical text. In it, Euclid proposed that a line can be divided into what he called its "extreme and mean ratio." In mathematical terms that disguised the aesthetic simplicity of his ideas, he wrote in Book IV of *Elements*, "A straight line is said to have been cut in extreme and mean ratio when, as the whole line is to the greater segments, so is the greater to the lesser."

Stated simply, Euclid proposed the possibility of dividing a line into two segments such that the ratio of the whole line to the larger segment is the same as the ratio between the larger and the smaller segments. If we call the endpoints of Euclid's straight line A and C, and its dividing point B, then mathematically the ratio of the line $\overline{AC}$ to its larger segment, $\overline{AB}$, is equal to the ratio of line segments $\overline{BC}$ to $\overline{AB}$. Numerically:

$$\overline{AB}+\overline{BC}=\overline{AC} \quad \text{and} \quad \frac{\overline{AB}}{\overline{AC}}=\frac{\overline{BC}}{\overline{AB}}$$

Euclid found that, using algebra, it's possible to solve the number relating $\overline{AB}$ to $\overline{BC}$. (Hint: If you eliminate $\overline{AC}$ and simplify, you will get a quadratic equation.) This number is the "golden ratio," Φ, which relates the size of the larger segment to the smaller segment, as:

$$\frac{\overline{AB}}{\overline{BC}}=\frac{1+\sqrt{5}}{2}=1.61803399887\ldots$$

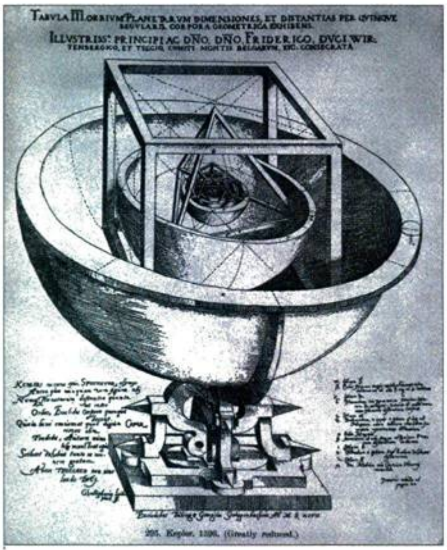
This particular ratio is a special number like π that is made up of a never-ending, never-repeating sequence.

The significance of Euclid's find extended beyond mathematical curiosity, however. The number's allure stems primarily from its propensity to pop up where it's least expected. This ratio describes such divergent systems as seashells, galaxies, and leaves. In the centuries that followed Euclid's publication of *Elements*, mathematicians struggled to find an appropriate honorific that more properly described this ratio's mathematical elegance. It was called the "divine proportion" in a book published by mathematician Luca Pacioli in 1509. In a series of books started in 1835 by mathematician Martin Ohm it was called the "golden section," "golden ratio," and "golden number." To honor its application in art, 20th-century mathematician Mark Barr gave the ratio the designation phi (Φ). This is the first letter in the name of the great Greek sculptor Phidias (ca. 490–430 B.C.), who many people believe used the golden ratio in proportioning his sculptures.

## Magically recurring ratio

The golden ratio has captivated mathematicians and scientists for so long because it keeps being rediscovered in new and often unexpected places in nature. A trip through a forest will bring you face to face with a leafy example. Botanists use the term *phyllotaxis* to describe how leaves are arranged on plants. Successive leaves tend to spiral around the branch with the same angle separating each new leaf. This angle, common across many different plants, is 137.5°. If we take the 360° that fills out an entire circle and divide it into two angles that conform to the golden ratio, the smaller angle (the smaller segment of our now angular line) is 137.5°.

The logarithmic spiral provides an example that is more relevant to astronomy. Nature appears to have chosen the logarithmic spiral as one of its favorite shapes — we encounter this curve in phenomena as diverse as the shells of mollusks and giant spiral galaxies. The distances between the "coils" in a logarithmic spiral increase as they move away from the source. In galaxies the source is the galactic center, and in shells the source, mathematically called the "pole," corresponds to the shell's central cusp. As the spiral grows,


TABVLA III. ORBIVM PLANETARVM DIMENSIONES, ET DISTANTIAS PER QVINQVE REGVLARIA CORPORA GEOMETRICA EXHIBENS.
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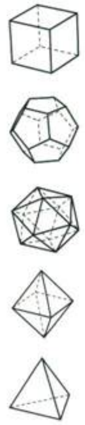
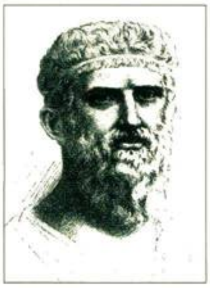


**NESTED SOLIDS** inscribed the planetary orbits of Kepler's early solar system model. Published in *Mysterium Cosmographicum*, the model outlines Kepler's associations between Platonic solids and the planets on the basis of their geometrical, astrological, and metaphysical attributes. Left: The golden ratio is embedded in such geometric forms as those found in Kepler's nested solid solar system (top to bottom): a cube, dodecahedron, icosahedron, octahedron, and tetrahedron. CORBIS

**EUCLID** produced the book *Elements*, defining geometry and number theory. He discovered the golden ratio after searching for relationships between line segments, not realizing its significance. CORBIS



**PLATO** saw Nature in terms of perfect shapes and idealized mathematical formulae. To Plato symmetry was supreme, and he proposed the famous four-element universe of earth, water, air, and fire. CORBIS

**KEPLER** greatly admired the golden ratio, believing it was a fundamental part of God's plan for the cosmos. "I believe this geometrical proportion served as idea to the Creator," wrote the astronomer. CORBIS

the distance of the coil from the center increases with the same ratio for every equal increase in angle. This is best understood geometrically using the golden ratio to trace out increasingly larger squares within rectangles.

For example, take a golden rectangle, where the ratio of the length ($\overline{AB}$) to the height ($\overline{BC}$) is equal to $\Phi$. Make a square inside this rectangle and then draw a square outside the rectangle. The new rectangles are also golden rectangles and the ratio between these squares is the golden ratio. If you connect the successive points where these whirling squares divide the sides of the rectangles into golden ratios, you will trace a logarithmic spiral.

Geometrically elegant, this form defines the growth patterns of mollusk shells and, more strangely, the propagation of star formation in spiral galaxies. The spiral arms of galaxies are not attached to disk material. If they were, they would not survive for long because different rings of a galactic disk rotate at different speeds. Rather, the arms represent density waves — waves of compression that sweep through the disk and squeeze gas clouds along their way, thereby triggering star formation.

Once we realize how ubiquitous the golden ratio is in nature, it comes as no surprise that a few famous cosmologists have shown great interest in the ratio. The most eloquent of these was Johannes Kepler (1571–1630), who wrote: "Geometry has two great treasures. One is the Theorem of Pythagoras; the other, the division of a line into extreme and mean ratio. The first we may compare to a measure of gold; the second we may call a precious jewel."

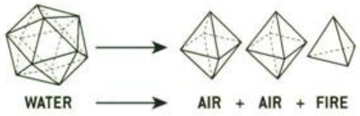
## Mediterranean roots

Along with turning up in nature, the golden ratio has crept into human philosophy and our theoretical models of the universe. Plato (428/427 B.C.–348/347 B.C.) prophesied the significance of $\Phi$ even before Euclid articulated his "extreme and mean ratio." Dying not quite two decades before the establishment of the Museum in Alexandria, this great Greek philosopher saw the world in terms of perfect shapes and idealized mathematical formulations. Plato was not a great mathematician in his own right, but he recognized beauty in the geometrical formulations of those around him. Key to Plato's thinking was the idea of symmetry, and he borrowed his Platonic solids from the mathematician Theaetetus. Working outside Plato's Academy, Theaetetus demonstrated that five regular solids can be created with every face sharing the same shape. Remarkably, the volume of two of these forms contains a factor of $\Phi$.

Equilateral triangles form the fundamental shape behind three of these solids: the tetrahedron (four faces), the octahedron (eight faces), and the icosahedron (twenty faces). The other two solids, the cube (six faces) and the dodecahedron (twelve faces), are made from the square and the regular pentagram. The volumes of the dodecahedron and icosahedron are expressible in terms of the golden ratio, $\Phi$. An icosahedron with edges that are one unit long has a volume of $5\Phi^5 \div 6$. The volume of a dodecahedron with an edge length of one unit is $5\Phi^3 \div (6-2\Phi)$. Additionally, the twelve vertices of the icosahedron can be divided into three groups of four, with the vertices of each group forming a golden rectangle.

Plato (following Empedocles) divided his cosmos into four basic elements — earth, water, air, and fire — and to each element he assigned one of the regular solids. The stable cube represented Earth, the pointy tetrahedron iconified fire, the "mobile" octahedron was air, and the multifaceted icosahedron became water. To Plato, "[The dodecahedron is that] which the god used for embroidering the constellations on the whole heaven."

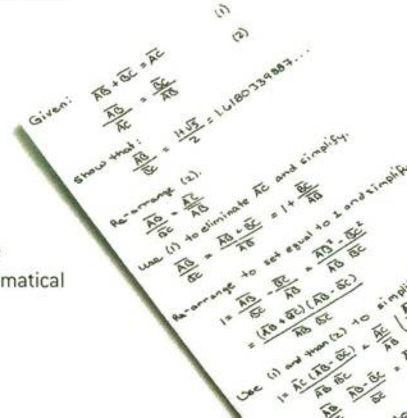
On this elemental foundation, Plato developed a "chemistry" whose basic ideas were not substantially different from John Dalton's 19th-century formulation of modern chemistry. For example, Plato suggested that when water is heated by fire it transforms into two particles of air (vapor) and one particle of fire. In the notation of a chemical reaction this may be written as:



In this formulation, the number of faces on each shape is used to balance the reaction. In this example, when you add up the number of faces on the Platonic solids you get 20 faces —> (2 x 8 faces) + 4 faces. These 4 (+1) fundamental elements were the building blocks of all matter and energy in Plato's modeling of the universe.

Plato introduced symmetry and geometry into cosmology, and through the volumes and surface areas of two of his solids, brought forward the golden ratio as a minor actor in the universe. Claudius Ptolemy (*ca.* A.D. 150) was the first scientist to deeply explore the golden ratio and offer it a place at center stage. While he is best known for his geocentric model

**BACK OF THE ENVELOPE CALCULATIONS** can be used to find the number behind $\Phi$. Nature, unlike man, requires no such mathematical gymnastics to make its proportions golden.



Given: $\overline{AB}+\overline{BC}=\overline{AC}$ (1)

$\frac{\overline{AB}}{\overline{AC}} = \frac{\overline{BC}}{\overline{AB}}$ (2)

Show that: $\frac{\overline{AB}}{\overline{BC}} = \frac{1+\sqrt{5}}{2} = 1.6180339887...$

Re-arrange (2).

$\frac{\overline{AB}}{\overline{BC}} = \frac{\overline{AC}}{\overline{AB}}$

Use (1) to eliminate $\overline{AC}$ and simplify.

$\frac{\overline{AB}}{\overline{BC}} = \frac{\overline{AB}+\overline{BC}}{\overline{AB}} = 1+\frac{\overline{BC}}{\overline{AB}}$

Re-arrange to set equal to 1 and simplify

$1 = \frac{\overline{AB}}{\overline{BC}} - \frac{\overline{BC}}{\overline{AB}} = \frac{\overline{AB}^2-\overline{BC}^2}{\overline{AB}\,\overline{BC}}$

$= \frac{(\overline{AB}+\overline{BC})(\overline{AB}-\overline{BC})}{\overline{AB}\,\overline{BC}}$

Use (1) and then (2) to simplify

$1 = \frac{\overline{AC}(\overline{AB}-\overline{BC})}{\overline{AB}\,\overline{BC}} = \frac{\overline{AC}}{\overline{AB}}$

$\frac{\overline{AB}-\overline{BC}}{\overline{BC}}$

/// FIBONACCI NUMBERS

**Kepler discovered another remarkable property** of the golden ratio — its relation to Fibonacci numbers. The Fibonacci series is named after the medieval mathematician Leonardo of Pisa (*ca.* 1170s–1240s), nicknamed Fibonacci.

In trying to solve an imaginary problem about the breeding of rabbits, Fibonacci discovered the series 1, 1, 2, 3, 5, 8, 13, 21, 34, . . . in which each new term equals the sum of the preceding two. Kepler discovered that if you look at the ratios of successive numbers (calculated here to three decimal places):

**1/1 = 1.000**
**2/1 = 2.000**
**3/2 = 1.500**
**5/3 = 1.667**
**8/5 = 1.600**
**13/8 = 1.625**
**21/13 = 1.615**
**34/21 = 1.619**
**55/34 = 1.618**
**89/55 = 1.618**

The ratios oscillate but continually approach the golden ratio. In Kepler's words, "The further we advance from the number one, the more perfect the example becomes."— M. L.

of the solar system, Ptolemy's most scientifically important contribution was perhaps his 13-volume text *Mathematike Syntaxis*. Written in Greek, this prodigious synthesis of all the astronomical knowledge of Ptolemy's time comes to us under the name *Almagest*. This name was bestowed by 9th-century Arab astronomers who referred to the text as "megiste," or "the greatest." In addition to writing the *Almagest*, Ptolemy authored the influential *Guide to Geography*. In both, Ptolemy provided the earliest equivalents of trigonometric tables. In them, he drew attention to the ratios of the length of the sides and base of triangles with the angles 36°, 72°, and 108°. These triangles are uniquely proportioned out of the golden ratio.

These "golden" triangles are formed from different combinations of the extreme and mean ratio and these three angles. A triangle with a base that supports two equal angles and two equal sides is called an isosceles triangle. The sides of a triangle with base angles of 72° resemble the longer line segment of our earlier line, while this triangle's base is identical to the shorter line segment. The ratio of the side to the base is our golden ratio $\Phi$. Similarly, if the triangle has base angles of 36° and a peak angle of 108°, the ratio of the base to the side is also $\Phi$. While Ptolemy is most often discussed as a cosmologist, through his mathematical explorations he gave homage to the golden ratio. Kepler, several hundred years later, would give $\Phi$ a place in the heavens.

## Golden renaissance

During the 16th century's scientific renaissance, European mathematicians and natural philosophers turned to the works of antiquity for guidance and inspiration. Johannes Kepler (1571–1630) held great admiration for the golden ratio, as he believed that it served as a fundamental tool in God's creation of the universe.

Kepler's intriguing combination of a scientist's logic with Christian beliefs flavored all of his scientific endeavors. Referring to the golden ratio as the "divine proportion," Kepler wrote: "I believe that this geometrical proportion served as idea to the Creator when He introduced the creation of likeness out of likeness, which also continues indefinitely.

"I see the number five in almost all blossoms which lead the way for a fruit — that is, for creation — and which exist not for their own sake, but for that of the fruit to follow. Almost all tree-blossoms can be included here. . . . In geometry, the number five (that is, the pentagon) is constructed by means of the divine proportion which I [assume to be] the prototype for the Creation.

"Furthermore, there exists between the movement of the Sun (or, as I believe, the Earth) and that of Venus . . . the ratio of 8 to 13, which as we shall hear comes very close to the divine proportion.

"Lastly, according to Copernicus, the Earth-sphere is midway between the spheres of Mars and Venus. One obtains the proportion between them from the dodecahedron and the icosahedron, which in geometry are both derivatives of the divine proportion."

Kepler seized on this last idea and used the Platonic solids to build a model of the solar system that, to us, looks fantastic — even outrageous. It appeared in his 1596 book *Mysterium Cosmographicum*, or *The Cosmographic Mystery*. In this book, Kepler's main purpose was to answer two major questions: Why were there precisely six planets (In Kepler's time only the planets Mercury, Venus, Earth, Mars, Jupiter, and Saturn were known), and what determined the spacing between the planetary orbits?

Today, asking questions like these of the universe is normal, but in Kepler's day, asking "why" and "what" represented a revolution in astronomical thinking. Earlier astronomers the world over had been content to record their observations and look for trends that allowed them to make future predictions. These models, which included works by Ptolemy, were often cumbersome and lacked any central explanation of why specific celestial motions were observed. Unlike his historical peers, Kepler sought a theory that would explain the "why" behind the observations.

The full title of *Mysterium Cosmographicum* gives an idea of what he was after. It reads: "A precursor to cosmographical dissertations, containing the cosmic mystery of the admirable proportions of the Celestial Spheres, and of the time and proper causes of their numbers, sizes, and periodic motions of the heavens, demonstrated by the five regular geometric solids."

Kepler, recognizing that the Sun is the true center of the solar system, was a committed Copernican. In developing his heliocentric model for the solar system, he initially turned to the five Platonic solids and Aristotle's perfect sphere as guiding shapes. He proposed that, taken as boundaries, the five solids and an outer celestial sphere determine precisely the six spacings for the six planets. Furthermore, his imaginative model of nested geometrical forms was designed to also explain the sizes of the planets' orbits.

In Kepler's words: "The Earth's sphere is the measure of all other orbits. Circumscribe a dodecahedron around it. The sphere surrounding it will be that of Mars. Circumscribe a tetrahedron around Mars. The sphere surrounding it will be that of Jupiter. Circumscribe a cube around Jupiter. The surrounding sphere will be that of Saturn. Now, inscribe an icosahedron inside the orbit of Earth. The sphere inscribed in it will be that of Venus. Inscribe an octahedron

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**Mario Livio** *is head of the Science Division at the Space Telescope Science Institute in Baltimore. He is the author of* The Golden Ratio *(Broadway Books, 2002).*

inside Venus. The sphere inscribed in it will be that of Mercury. There you have the basis for the number of the planets."

From a seemingly absurd starting point, Kepler would go on to create the first mathematically rigorous and accurate model of planetary motion. For all its preposterous nature, Kepler's initial geometric model marked a true turning point in the history of science.

## The golden age of astronomy

Following Kepler, the story of the golden ratio and cosmologists would wait nearly four centuries for a new chapter to be written. Cosmologist Roger Penrose at Oxford, England, and physicist Paul Steinhardt at Princeton, New Jersey would re-enliven this numerical tale.

Like Ptolemy, both these men are known for their cosmology research, but both are also accomplished mathematicians. Penrose, while investigating Einstein's theories in the extreme case of black hole formation, was the first to recognize a scientific discontinuity between quantum mechanics and relativity. Steinhardt was a key figure in the development of the current inflationary model of the universe. Beyond their theoretical explorations of the distant universe, these cosmologists are also attracted to the golden ratio and its more earthly appearance in the field of quasicrystals.

The majority of solids are either amorphous or crystalline in nature. Examined under the highest possible magnifications, amorphous materials such as glass appear to be made of atoms that are jumbled together with no ordered structure. Crystalline structures such as table salt (sodium chloride) form from unit cells of grouped atoms with a repeating structure. Just as with a perfectly tiled floor, the orientation of each unit cell uniquely determines the entire pattern. For many decades, scientists have known that shapes with fourfold symmetry (for example, squares), threefold symmetry (triangles), and sixfold symmetry (hexagons) can fill a plane surface and are used by nature to build crystals. At the same time, scientists long believed that crystals with fivefold symmetry could not exist.

In 1984, a team of researchers led by Israeli materials engineer Dany Schectman discovered that crystals of an aluminum manganese alloy exhibit five-fold symmetry. This means their structure appears the same when the crystal is viewed after being rotated a fifth of a circle, or 360° ÷ 5 – 72°. This discovery shocked crystallographers as much as the discovery of a herd of five-legged cows would jolt zoologists. Schectman's crystals demonstrated that another state of matter, dubbed "quasicrystals," exists and shares important aspects with both crystalline and amorphous substances.

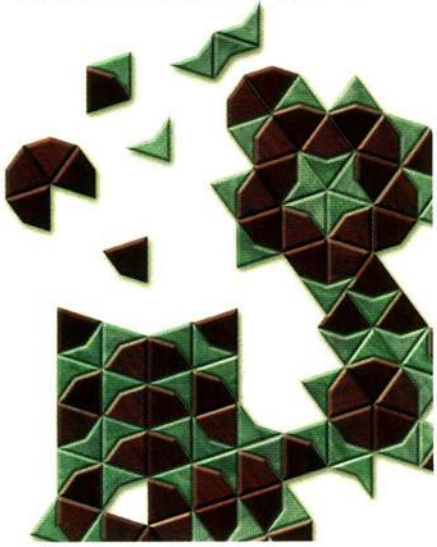
It did not take physicists long, however, to realize that a 1974 discovery in recreational mathematics by Penrose could shed light on the quasicrystals mystery. Penrose was fascinated with finding a non-periodic set of shapes that could be used to fill a plane or tile a floor. After years of searching he found two basic shapes of tiles, called darts and kites, that can fit together to fill a plane. Darts and kites exhibit the "forbidden" fivefold symmetry and are derived from different combinations of Ptolemy's golden triangles. The patterns they produce are not strictly periodic, but they do display a long-range order — precisely the properties of quasicrystals. Furthermore, if you count the number of each shape that is needed to fill an area, the ratio of the kites to darts approaches **Φ** as the area gets larger and larger.

The next logical step required finding a physical explanation to link the Penrose Tiles to the five-fold symmetry of quasicrystals. German mathematician Petra Gummelt laid down the foundation for this explanation. He noted in 1996 that Penrose tiling could be obtained by using decagon tiles, if they were allowed to overlap according to certain rules. Steinhardt and Korean physicist Hyeong-Chai Jeong demonstrated that overlapping simply corresponds to neighboring clusters of atoms sharing atoms. Images of the surfaces of some quasicrystals show flat "terraces" terminating in steps that come primarily in two heights. The ratio of the two heights precisely equals the golden ratio.

Remarkably, it was the work of two cosmologists, scientists interested in the largest scales imaginable, who determined the nature of miniscule atomic formations. The love affair between the golden ratio and astronomy does not end, however, with the story of people who are simply interested in both. In addition to creeping into the atomic realm, the golden ratio has hidden itself among the heavens.

### /// GOLD ACCORDING TO PENROSE

**Penrose Tiles**, named for the British cosmologist Roger Penrose, express five-fold symmetry. Created from pairs of golden triangles, these four-sided polygons can be used to fill a plane. As the area increases, the ratio of "darts" to "kites" approaches **Φ**.



Self-gravitating systems, such as stars, often have the peculiar property of heating up when they lose energy. A star like the Sun, for example, contracts upon losing energy and ends up hotter. Black holes that do not rotate (Schwarzschild black holes) behave the same way. However, rotating black holes (Kerr black holes) can undergo an interesting phase transition in which they transform from a state with negative specific heat into one with positive specific heat. Surprisingly, physicist Paul Davies showed that this transition occurs when the ratio of the square of the mass of the black hole to the square of its angular momentum (in appropriate units) equals the golden ratio.

The golden ratio will undoubtedly continue to create surprises, and it is precisely this feeling of amazement that makes this number so appealing. Einstein recognized the importance of surprise in intellectual endeavors, saying, "The fairest thing we can experience is the mysterious. . . . He who knows it not and can no longer wonder, no longer feels amazement, is as good as dead, a snuffed-out candle."

NEXSTAR®
4GT
5i
8i

# Three To Get Ready.

## Get set to go to a new level of astronomical viewing with these affordable computerized telescopes.

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### Improved features include:

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- **Slew Limits** — Sets the limit that the telescope can slew in altitude.
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### NexStar 5i and 8i - Expand your system as you expand your horizons.

The NexStar 5i and 8i include all of Celestron's newest hardware and software enhancements in an affordable and expandable system. Most important, these two new NexStar's will fully align themselves when used with the **optional CN16 GPS Accessory (#93963)**. Put the power of our newest software features and expanded object database to work with the **optional computerized hand control**.

NEW LOWER PRICE!

◀ NexStar® 4GT

NexStar® 4GT
$499*
+ $40 Shipping & Handling
Shown on Optional Tripod: $149

### Optional Computerized Hand Control (#93962) features include:

- **Database Filter Limits** — User-defined filter limits; only objects visible above the horizon are displayed on the hand control.
- **User-defined Slew Limits** — Prevents slewing beyond the user- defined horizon.
- **GPS Align Compatible** — When used with the optional CN16 GPS Accessory.
- **Hibernate** — Allows the NexStar to retain its star alignment even when powered down.
- **40,000 Object Database** — With custom lists of all of the most popular deep sky and stellar objects.

NexStar® 8i
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+ $75 Shipping & Handling
Optional Computerized Hand Control: $149
Optional Tripod: $149

◀ NexStar® 8i

NexStar 8i shown with optional Computerized Hand Control, Tripod, 1.25" Ultima Ocular, and CN16 GPS Accessory.

### New Software Features:

- **Compass Calibration** — Allows you to point to true north more accurately by compensating for magnetic north offset and local anomalies.
- **Polar Alignment Routine** — Facilitates polar alignment for CCD imaging or conventional 35mm astrophotography.
- **EQ AutoAlign** — Now the patented AutoAlign is available even when the telescope is mounted on a wedge.
- **Database Filter Limits** — Available in Equatorial mode as well as Alt/Az.

### New Hardware Features:

- **AutoGuide Port** — Easy connection of AutoGuider for astrophotography.
- **Auxiliary Port** — Use for accessories like the optional CN16 GPS Accessory.

NexStar® 5i
$899*
+ $50 Shipping & Handling
Optional Computerized Hand Control: $149
Optional Tripod: $149

NexStar® 5i ▶

NexStar 5i shown with optional Computerized Hand Control, Tripod, and optional accessories for astrophotography.

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Computerized capabilities like Auto Align, automatic Tour Function, easy-to-use hand control and 4,000+ object database all help make the NexStar 4GT a superstar telescope at a super affordable cost. The NexStar 4GT's deluxe features combine with Celestron's uncompromising optical standards to give amateur astronomers one of the most sophisticated and easy to use telescopes available on the market today.

NexStar® 4GT

**$499***

+ $40 Shipping & Handling

NexStar 4GT shown on optional tripod (Tripod #93497- $149)

### Improved Features Include:

- **Two-star alignment** — Allows you to do a two-star alignment just like other NexStar GoTo telescopes.
- **Quick-Align** — Allows the telescope to align itself without being aimed at two alignment stars.Works the same as the NX 8GPS and 11 GPS.
- **Filter Limits** — Displays only those objects within the set altitude filter limits. Works the same as NX 8GPS and 11GPS except the hand control displays a warning if there are no objects within the set filter limits.
- **Slew Limits** — Sets the limit that the telescope can slew in altitude. Will display a warning if you try to slew outside of your slew limits. Works the same as the NX 8GPS and 11GPS.
- **RS-232 Compatible** — Allows the telescope to communicate with a computer. Works with popular astronomy software such as "The Sky" or "Starry Night".

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BY MARTIN RATCLIFFE AND ALISTER LING

## APRIL 03

Mercury's best evening apparition of the year highlights a spring sky chock full of exciting planetary action.

# Mercury leads the planet parade

Forty-five minutes after the Sun sets, the spring lineup of planets comes to life as the orange glow of twilight fuses into the deepening blue above. On April 3 and 4, don't miss the dazzling string that starts with the crescent Moon and climbs through Saturn to Jupiter high in the south. With a little perseverance, you can easily add Mercury to the billing.

The wing-footed innermost planet puts on its best evening show of the year for Northern Hemisphere observers. Scan the sky near the horizon with binoculars to catch its starlike yellow glow. There is no bright star in the neighborhood to confuse the identification. Soon you will be able to follow it with the naked eye as it climbs into a darker sky during the next two weeks. As Mercury's phase thins, its brightness drops from night to night; by the 20th, you'll probably need binoculars to spot it.

A very pale, slender crescent Moon floats to Mercury's left on the 2nd. It's only 28 hours old for observers on the East Coast. By the 7th, it has vaulted to a position just above Saturn.

**MERCURY PIERCES** the twilight glow these April evenings, much as it did in March 1999, when it lay to the right of Jupiter. GEORGE LIV

The closest Full Moon of the year comes on April 16. Tidal regions of Earth will experience significant swings in ocean height. Next November's Full Moon will appear noticeably smaller if you compare the two with the same eyepiece. Photographs made with an identical set-up will show the difference as well.

Why do the planets make a line in the sky? Imagine a baseball field from the perspective of an ant. If the Sun is the pitcher, then Earth lies about halfway between the pitcher's mound and second base, and the baselines form a circle around us. But because our eyes are at grass level, it looks like one straight line as we turn around. Jupiter is at first base, Saturn is halfway to first base, and Mercury is currently a spinning ball rolling out from home plate. Mercury then rolls between us and the Sun, and we lose it in the glare.

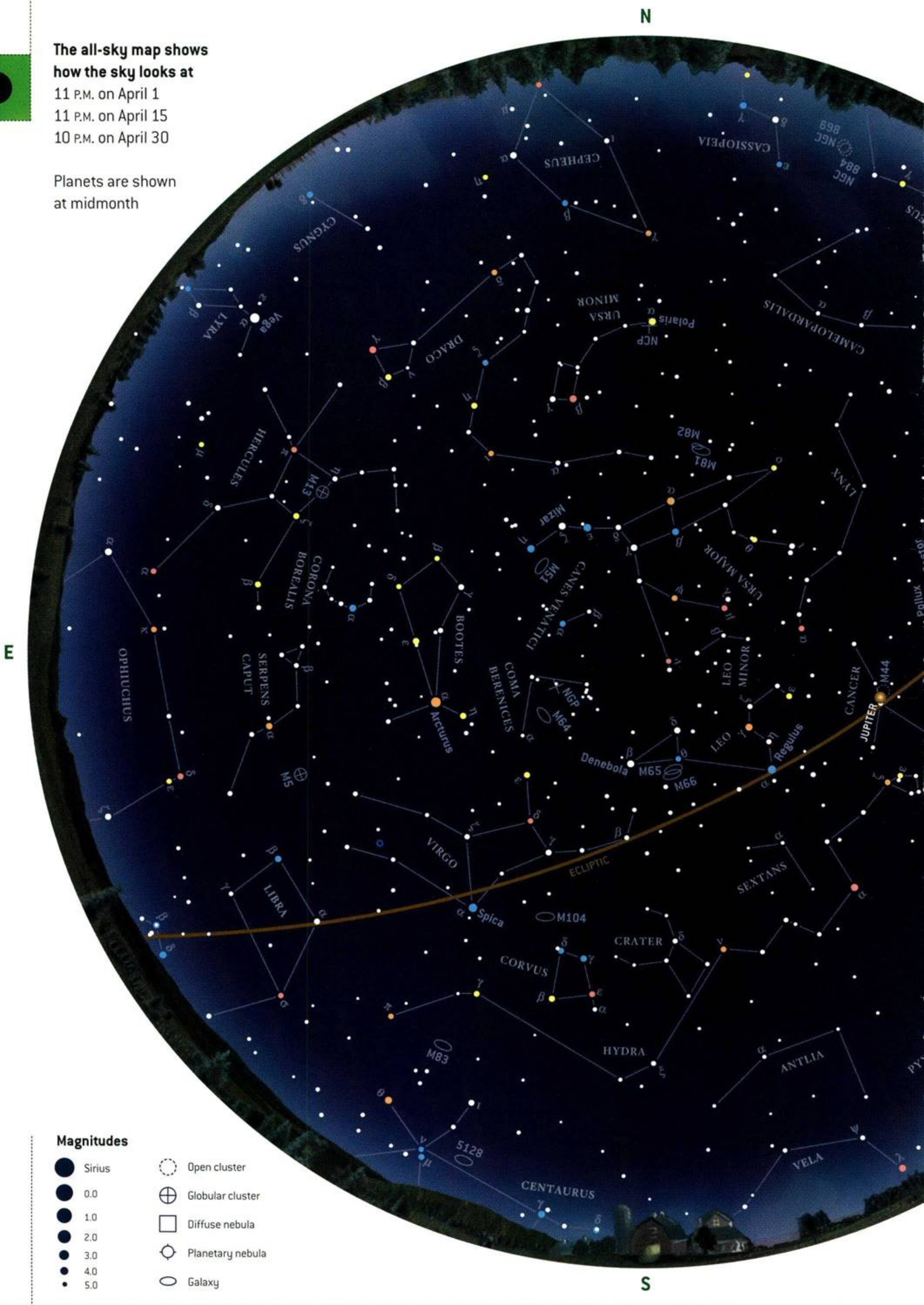
The Moon hits a home run every month, gliding past Jupiter on the 10th, rounding second base at full phase, and passing ruddy Mars at third base by the 23rd. But the solar system is three-dimensional, and the Moon in reality stays close to Earth, only appearing to be as far away as the bases because of perspective.

It may come as a surprise that you can see a space rock with the naked eye. A dark country sky and a detailed map are all you need. One of the larger asteroids, 4 Vesta, currently glows at 6th magnitude. It will also be easy to follow through binoculars from a city backyard.

With only one year to wait for the bright comet C/2001 Q4 (NEAT) to arrive, we must satisfy ourselves with the dirty snowball called C/2001 RX14 (LINEAR). With a 4-inch scope away from city lights, you can follow its path toward the brighter galaxies of Leo and Virgo. Coincidentally, our featured deep-sky galaxies this month were discovered by observers following comets more than 220 years ago.

**The all-sky map shows how the sky looks at**
11 P.M. on April 1
11 P.M. on April 15
10 P.M. on April 30

Planets are shown at midmonth


N
E
S
CEPHEUS
CASSIOPEIA
NGC 869
NGC 884
CYGNUS
LYRA
Vega
URSA MINOR
Polaris
NCP
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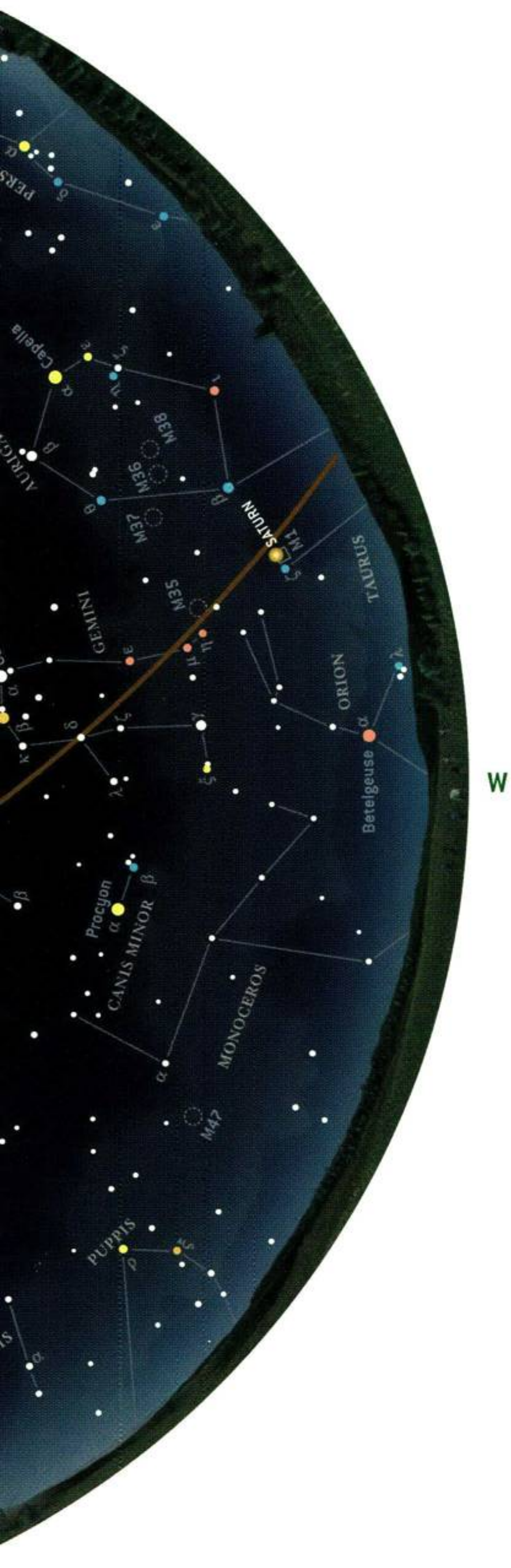
DRACO
M82
M81
HERCULES
M13
LYNX
Mizar
M51
CANES VENATICI
CORONA BOREALIS
URSA MAJOR
BOOTES
OPHIUCHUS
SERPENS CAPUT
COMA BERENICES
NGP
M64
Arcturus
LEO MINOR
LEO
CANCER
M44
JUPITER
Pollux
Regulus
Denebola
M65
M66
M5
VIRGO
ECLIPTIC
LIBRA
Spica
M104
SEXTANS
CRATER
CORVUS
HYDRA
ANTLIA
M83
5128
CENTAURUS
VELA

**Magnitudes**

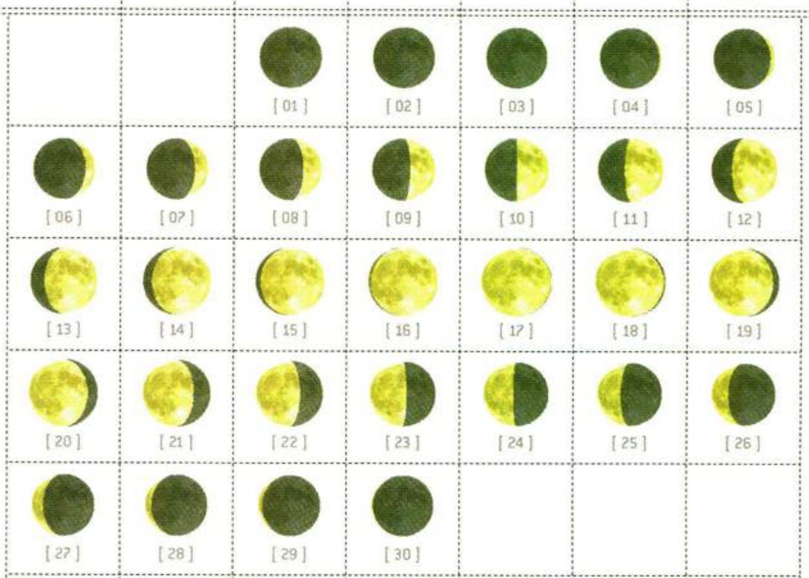
- ● Sirius
- ● 0.0
- ● 1.0
- ● 2.0
- ● 3.0
- ● 4.0
- • 5.0

- ◌ Open cluster
- ⊕ Globular cluster
- □ Diffuse nebula
- ⌖ Planetary nebula
- ⬭ Galaxy

This map portrays the sky at times shown in the upper left corner of the page. Located just outside the map are the four directions: north, south, east, and west. To
overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.


PERS
Capella
AURIG
M38
M36
M37
SATURN
M1
TAURUS
GEMINI
M35
ORION
Betelgeuse
Procyon
CANIS MINOR
MONOCEROS
M47
PUPPIS
W

# april 03



| SUN. | MON. | TUES. | WED. | THURS. | FRI. | SAT. |
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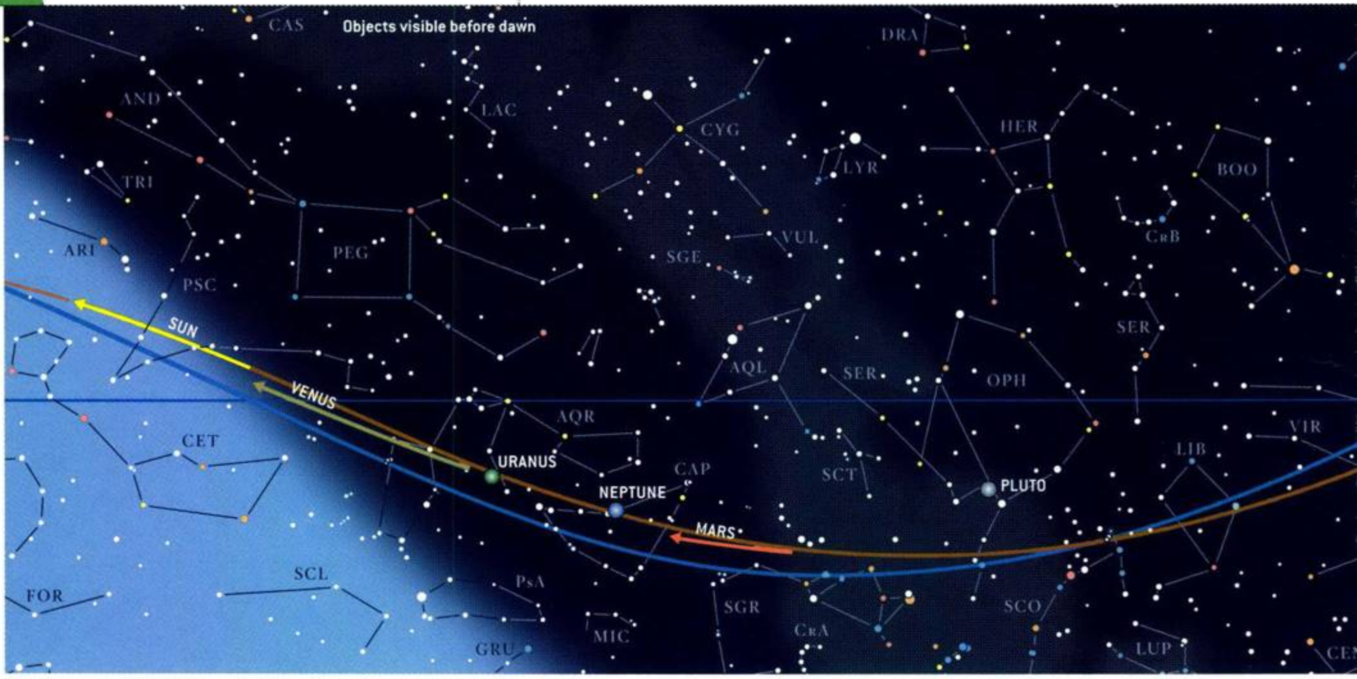
| [27] | [28] | [29] | [30] | | | |
| | | | | | | |

| | |
|---|---|
| **01** | New Moon is at 2:19 P.M. EST |
| **03** | The Moon is at apogee (252,407 miles from Earth), 11:29 P.M. EST<br>Jupiter is stationary, midnight EST |
| **07** | The Moon passes 3° north of Saturn, 6 P.M. EDT |
| **09** | First Quarter Moon is at 7:40 P.M. EDT |
| **11** | The Moon passes 4° north of Jupiter, 4 A.M. EDT |
| **16** | Mercury is at greatest eastern elongation (20°), 11 A.M. EDT<br>Full Moon is at 3:36 P.M. EDT |
| **17** | The Moon is at perigee (221,927 miles from Earth), 12:56 A.M. EDT |
| **22** | Lyrid meteor shower peaks |
| **23** | The Moon passes 3° south of Mars, 3 A.M. EDT<br>Last Quarter Moon is at 8:18 A.M. EDT<br>The Moon passes 5° south of Neptune, midnight EDT |
| **25** | The Moon passes 5° south of Uranus, noon EDT |
| **28** | The Moon passes 3° south of Venus, 1 P.M. EDT |

nd stars above your horizon, hold the map

## Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and s


Objects visible before dawn
CAS
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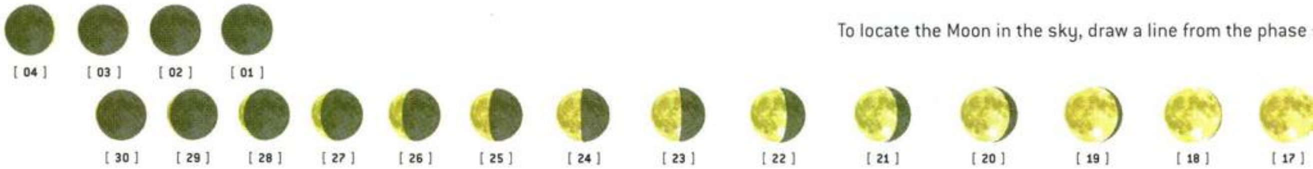
AND
LAC
CYG
HER
LYR
BOO
TRI
VUL
CrB
ARI
PEG
SGE
PSC
SUN
SER
AQL
SER
OPH
VENUS
AQR
VIR
CET
URANUS
CAP
LIB
SCT
PLUTO
NEPTUNE
MARS
SCL
PsA
SGR
SCO
FOR
CrA
MIC
GRU
LUP
CEN

To locate the Moon in the sky, draw a line from the phase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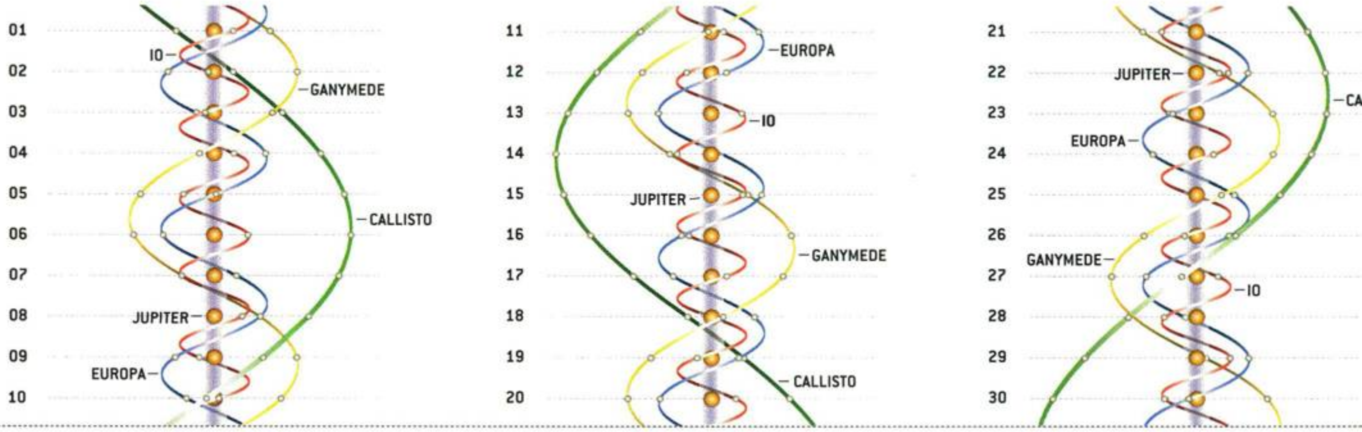
| PLANETS | MERCURY | MERCURY | VENUS | MARS |
|---|---|---|---|---|
| Date | April 1 | April 15 | April 15 | April 15 |
| Magnitude | –1.4 | –0.1 | –3.9 | 0.3 |
| Angular Size | 5.4" | 7.4" | 12.5" | 8.3" |
| Illumination | 91% | 45% | 83% | 87% |
| Distance (AU) from Earth | 1.237 | 0.909 | 1.330 | 1.125 |
| Distance (AU) from Sun | 0.311 | 0.339 | 0.728 | 1.492 |
| Right Ascension (2000.0) | 1h17.7m | 2h43.1m | 23h32.4m | 19h51.6m |
| Declination (2000.0) | 8°28' | 18°33' | –4°28' | –21°59' |

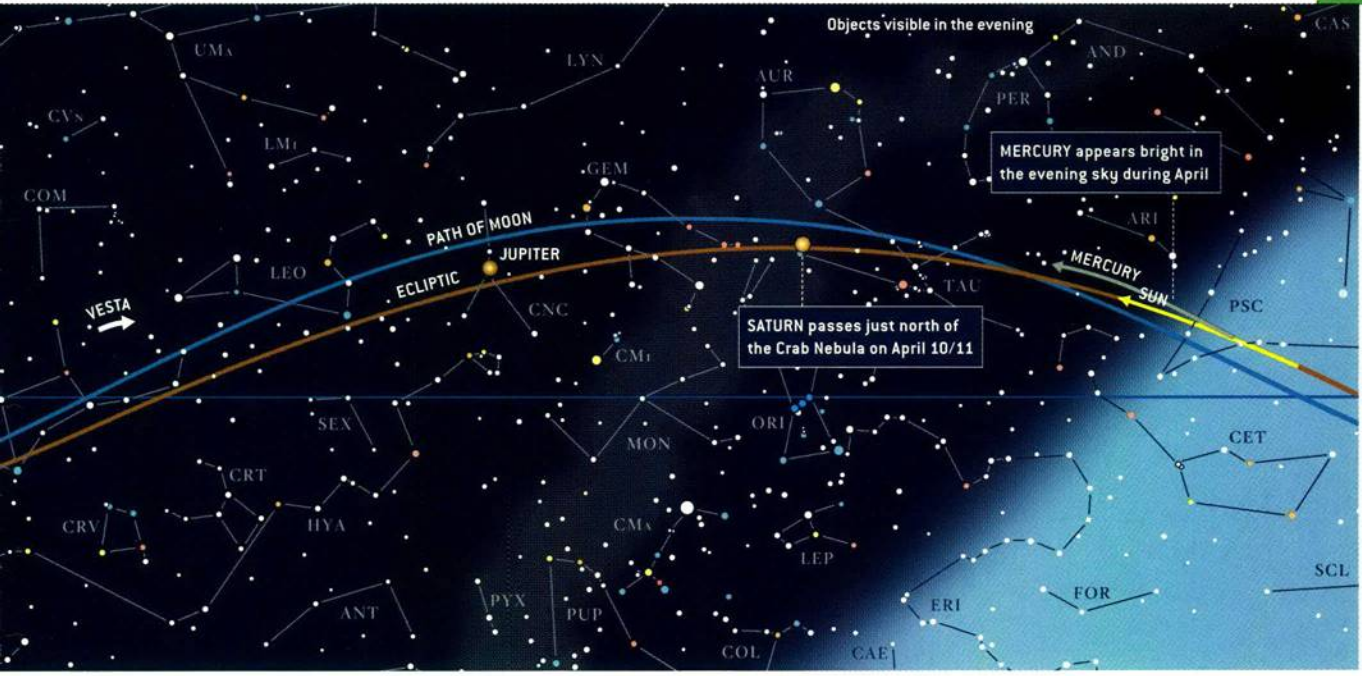
10"
S
W E
N

## Jupiter's moons

Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view in a telescope.



uares show motions and locations of solar system objects during the month.


Objects visible in the evening

MERCURY appears bright in the evening sky during April

SATURN passes just north of the Crab Nebula on April 10/11

CAS
UMA
LYN
AUR
AND
PER
CVN
LMI
COM
GEM
ARI
PATH OF MOON
JUPITER
MERCURY
SUN
ECLIPTIC
LEO
TAU
PSC
VESTA
CNC
CMI
SEX
ORI
MON
CET
CRT
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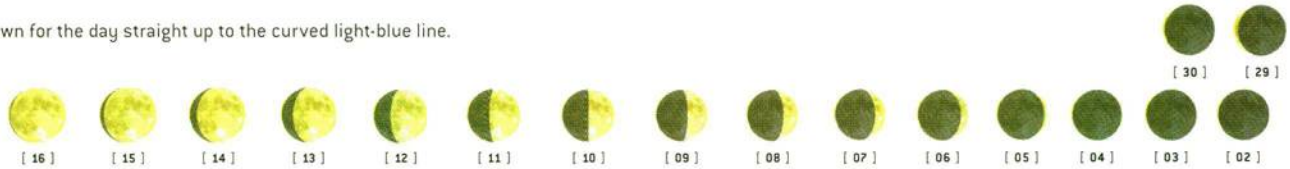
hown for the day straight up to the curved light-blue line.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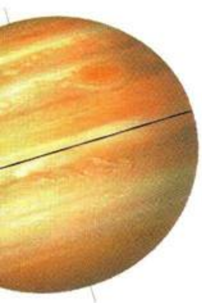
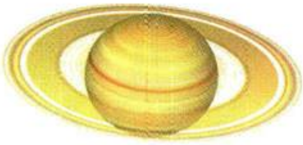
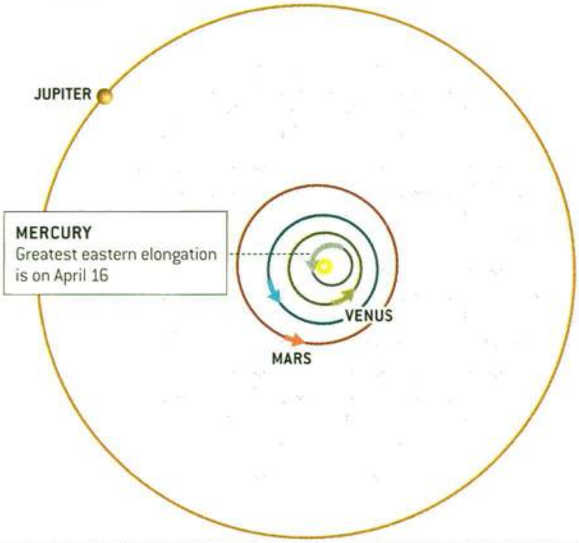




| JUPITER | SATURN | URANUS | NEPTUNE | PLUTO |
|---|---|---|---|---|
| April 15 | April 15 | April 15 | April 15 | April 15 |
| −2.2 | 0.1 | 5.9 | 7.9 | 13.8 |
| 39.4" | 17.5" | 3.4" | 2.2" | 0.1" |
| 99% | 100% | 100% | 100% | 100% |
| 5.009 | 9.494 | 20.611 | 30.382 | 30.059 |
| 5.335 | 9.032 | 20.022 | 30.082 | 30.635 |
| 8h43.4m | 5h36.0m | 22h15.8m | 21h01.4m | 17h18.4m |
| 19°03' | 22°22' | −11°34' | −16°55' | −13°35' |

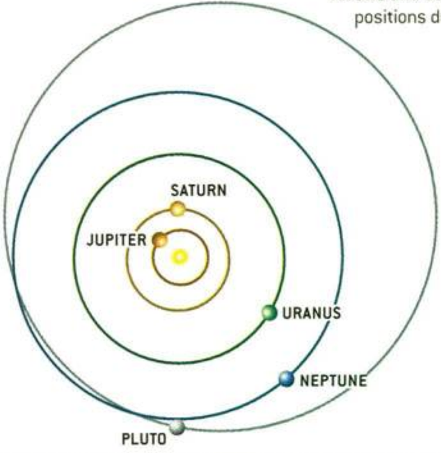
LLISTO


MERCURY
Greatest eastern elongation is on April 16

JUPITER
VENUS
MARS

## The planets in their orbits

Arrows and dots show planets' positions during the month.


SATURN
JUPITER
URANUS
NEPTUNE
PLUTO

# THE DEEP SKY

The southern reaches of Virgo provide a happy hunting ground for observers of bright galaxies and pulsating variable stars.

## A variable in Vesta's vicinity

If you're following the bright asteroid 4 Vesta through binoculars, take a few moments to aim one field south and monitor the pulsating star R Virginis. No one knows how bright it will get at the peak of its current maximum, expected at the end of March. It typically crests near 7th magnitude, glowing with a yellow-orange hue, but it has been known to climb as high as magnitude 6.2.

It's surprisingly easy to estimate the brightness of a variable star. First, use the chart at right and find one comparison star that's a bit brighter and another one that's slightly fainter. Then give R Virginis a number that fits nicely between the other two. For example, if it seems closer to the star labeled 71 than the 76 (decimal points have been omitted to avoid confusion with stars), call it magnitude 7.3.

## Southern end of the Virgo Cluster

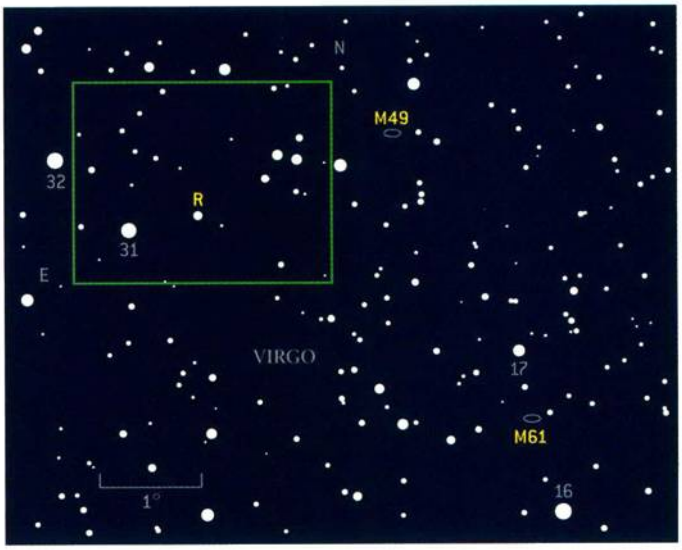
Floating in the distance, behind these sparse Virgo starfields, lie the bright galaxies M49 and M61. With a small telescope under a dark sky, you can see evidence of their different structures.

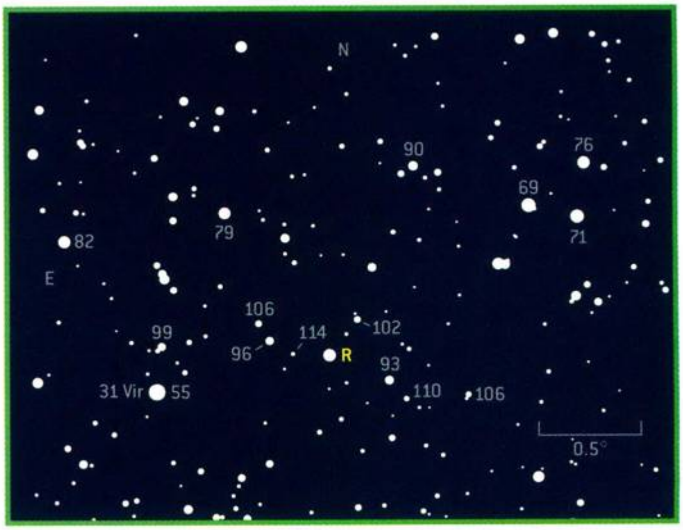
Avoid the glare of the Moon, which interferes noticeably during the middle two weeks of the month.

M49 is a massive elliptical galaxy, a huge, slightly oval ball containing hundreds of billions of stars that glows at magnitude 8.4. Outside a sharp core, the brightness drops off slowly toward the edge. It spans a respectable 8′, about one-quarter the diameter of the Moon from our point of view. It was the first galaxy in Virgo to be discovered by renowned comet hunter Charles Messier.

Eight years passed before Messier stumbled across the southern end of the Virgo Cluster while following the comet of 1779. He mistook M61 for the comet three times, by which point he realized that it wasn't moving. M61 is an almost face-on spiral galaxy, with a bright center and a diffuse circular halo. In telescopes bigger than 10-inches aperture, the two faint spiral arms can be seen winding outward.

If you take the time to study the character of the light, you may notice that M61's halo appears distinctly different from that of M49. Pump up the magnification to at least 150x, relax, and use averted vision, where you look off to the side while studying the middle. The spiral arms of M61 make for a mottled surface compared with M49's smooth appearance.





Messier wasn't the only comet hunter reporting nebulous objects. A 27-year-old Italian astronomer named Barnabus Oriani beat Messier to M61 by a mere six nights. Oriani had also discovered M49 and M60 a month earlier, although at the time he did not know that Messier had seen those first.

**SPIRAL GALAXY M61** belongs to the Virgo Cluster, although it lies well south of the cluster's crowded central region. JACK NEWTON

**Martin Ratcliffe** *is former President of the International Planetarium Society.* **Alister Ling** *is a meteorologist with Environment Canada.*

# THE PLANETS

Although Jupiter and Saturn continue to dominate the evening sky, Mercury climbs above the western horizon to make a fine planetary trio.

During April, Mercury puts on its finest evening display of the year. Its appearance in the darkening western sky sets the stage for nightfall and a string of planetary delights. These include Jupiter, shining brilliantly high in the south in the deepening twilight. Saturn hangs lower in the west, between the horns of Taurus the Bull. It's after midnight before Mars appears in the east, to be followed, as dawn lights the horizon, by Venus.

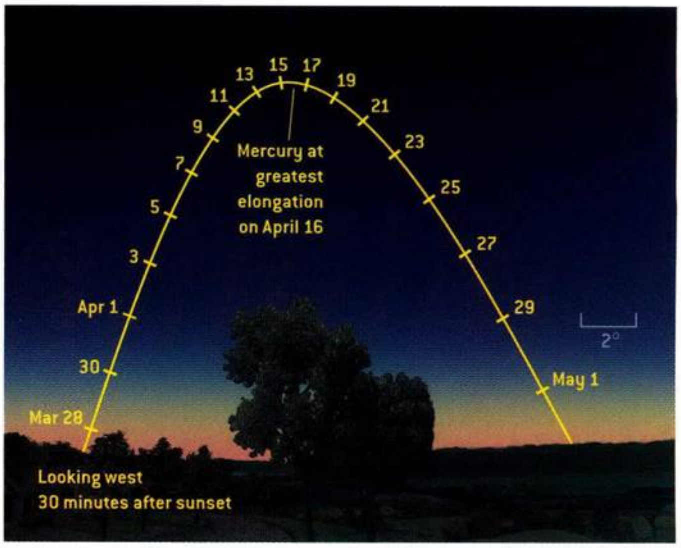
Thanks to the steep angle of the ecliptic to the western horizon at sunset during spring, **Mercury** climbs well into the twilight sky. This is the best view of the fleeting wanderer northerners will get during 2003. The best time to observe Mercury will be in the first three weeks of April. The planet appears brighter on the 1st, shining at magnitude –1.4, than on the 16th, when it has faded to magnitude 0.1. However, Mercury reaches greatest elongation from the Sun on April 16, so it appears higher in the sky than earlier in the month. This makes mid-April the easiest time to view the planet.

Mercury spends April moving along its orbit from the far side of the Sun to a point roughly between Earth and the Sun. Consequently, a telescope shows the fraction of illumination on Mercury's disk to be shrinking. During the first few weeks of April, the planet's phase wanes from gibbous to crescent. On April 1, about 90 percent of the disk is illuminated. By April 7, the disk appears three-quarters lit, and on the 16th, the percent illumination has dwindled to near 40 percent.

Mercury's disk never reaches any appreciable size, and it is nearly impossible to see any surface features on the planet through a telescope. However, experienced observers with large telescopes at sites with excellent seeing might spot some features. When Mercury shines brightly in early April, its disk measures 5″ across. By the 21st, the disk has grown to 9″, but the thin crescent then shimmers in the horizon haze. The crescent continues to thin as Mercury dips toward the horizon during the remainder of April.

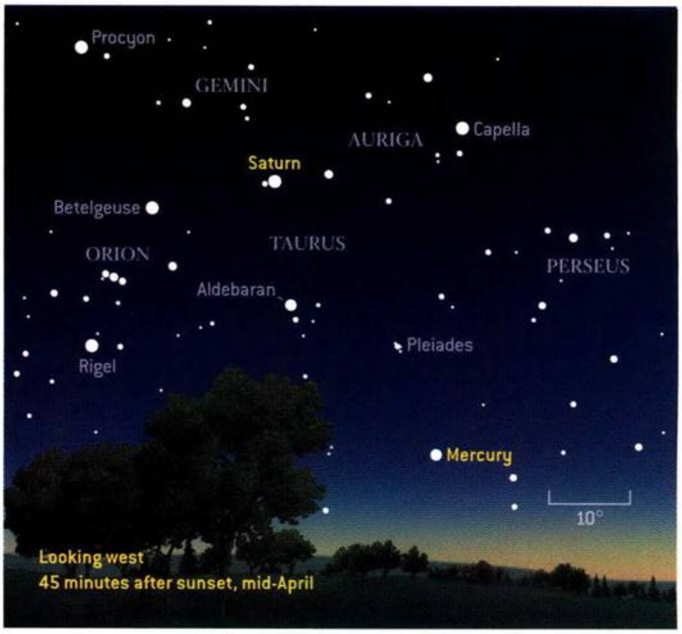
Moving along the ecliptic from Mercury, we find Taurus and that constellation's planetary visitor, **Saturn.** At magnitude 0.1, Saturn appears considerably brighter than Aldebaran, the 1st-magnitude star that marks the eye of the Bull. It remains visible most of the evening, setting near midnight. The planet is a spectacular sight in telescopes. The rings span 40″ and have their southern face tilted toward us at the maximum possible, yielding our best view since 1973.

Saturn's ring system makes the planet a "must-see" each evening. Three major rings are visible in most telescopes. These are labeled, from outer to inner, as rings A, B, and C. Ring B appears brightest, while Ring C glows so faintly it's elusive in small telescopes.



Mercury at greatest elongation on April 16

Looking west
30 minutes after sunset



Looking west
45 minutes after sunset, mid-April

In a near repeat of its spectacular transit of the Crab Nebula (M1) in January, Saturn makes a return visit this month. It slides 20′ north of the Crab's center on the night of April 10/11. The pair will fit in a single field of view at medium magnification, although you may have a hard time spotting the Crab's wispy tendrils in Saturn's glare.

**Jupiter** shines brilliantly at magnitude –2.2 in Cancer the Crab. As soon as the Sun sets, try to spot Jupiter high in the south. Once the sky grows dark, binoculars reveal that it lies less than two Moon-widths from the Beehive star cluster (M44). Jupiter remains on view all evening, sinking slowly toward the western horizon. It sets during the early morning hours.

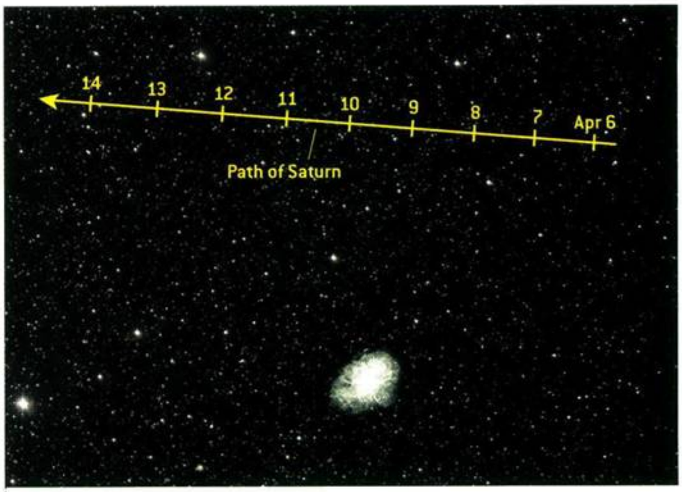
Jupiter looks stunning in almost any telescope. Its resident moons dance on either side of the globe, which this month appears nearly 40″ across. In addition to the bright satellites, Jupiter's atmosphere is full of detail. Jumping right out at you are the two equatorial belts — dark, linear features that span the disk from west to east.

All other features are subtler and require some patience to see. Study Jupiter carefully and the features will slowly become obvious. Dark and light spots, which are actually massive storms in the jovian atmosphere, sit at various locations. Jupiter's rapid spin means you can see the spots move noticeably within 15 to 20 minutes. The Great Red Spot, the most famous feature of all, has varied in visibility over the three centuries it has dominated Jupiter's southern hemisphere. Today its salmon color makes it tougher to spot than in years past.

Jupiter's moons continue their rare series of mutual events, in which they eclipse or occult one another. These events can occur only during brief times when the Sun and Earth lie in the plane of the satellites' orbits. Of the 39 mutual events during April, more than half can be seen from at least part of North America. (See "Shadow Play around Jupiter," December 2002). For a full list of events around the world, check out Astronomy.com. Here are a few April highlights:

On the American evening of April 3 (April 4 in Europe), Io's disk occults Europa at 11:04 P.M. EST (4:04 Universal Time) for 3.4 minutes. Later, at 12:47 A.M. EST (5:47 UT), the shadow of Io eclipses Europa for one minute. Six seconds after that eclipse ends, the shadow of Ganymede annularly eclipses Callisto at 12:48 A.M. EST (5:48 UT), lasting six minutes.

The early morning of April 19 sees Ganymede's shadow eclipse Io at 2:20 A.M. EDT (6:20 UT), ending four minutes later. This eclipse should be intriguing in two respects: First, Io dims by 86 percent, so it will nearly disappear from view; second, Ganymede lies in front of Jupiter while the eclipse takes place.

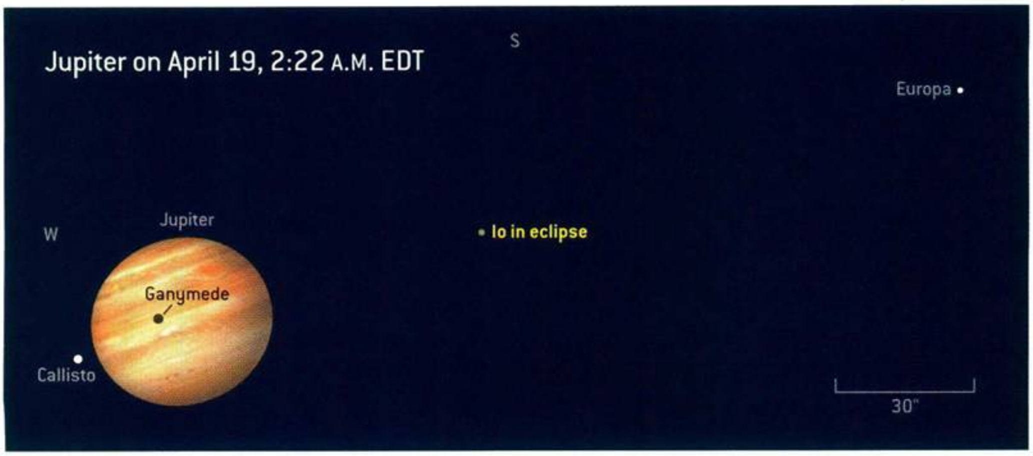


**SATURN SLIDES NORTH OF THE CRAB NEBULA** in April, missing the supernova remnant by just 20′. DIGITIZED SKY SURVEY/PALOMAR OBSERVATORY/STScI

**Mars** continues its slow but steady progress toward its best opposition in our lifetimes. It rises around 2 A.M. on April 1 among the stars of Sagittarius. On April 20 it passes one Moon diameter north of the globular cluster M75. By the end of April, Mars has brightened considerably, to magnitude 0.0. In the following 120 days, Mars will brighten by another three magnitudes, or a factor of 15.

Its apparent diameter is now approaching 10″ — a point at which serious telescopic observing of martian features can begin for most amateurs. The planet's gibbous disk will fill out during the summer months as Mars approaches opposition on August 28. And so begins the most active martian observing season in years — one that will last until December.

Brilliant **Venus** hangs low in the east at dawn. It shines at magnitude –3.9, and a telescope reveals a 13″-diameter disk that is currently 80-percent illuminated. It's starting to become a harder object to follow as its elongation from the Sun diminishes.



# METEORS AND MOONS

The dependable Lyrid meteor shower wins out over a gibbous Moon, which a week earlier presented a pretty, yet challenging, crater.

## Meteors stream from the Harp

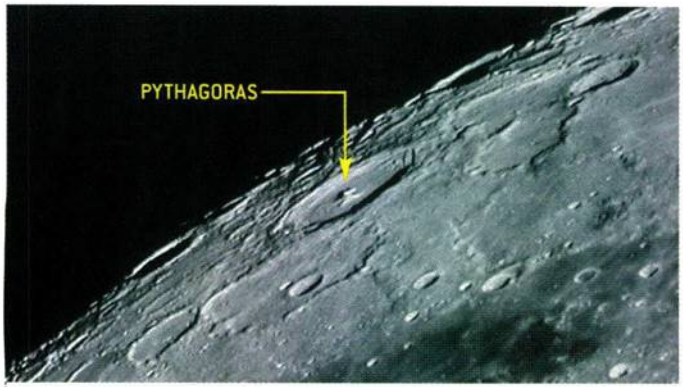
The Lyrid meteor shower is a stable one each year except for rare outbursts of activity, such as the 90 meteors per hour recorded in 1982. The shower is active from April 16 to 25, with this year's peak predicted for the afternoon of April 22. For observers in North America, the radiant on the Hercules-Lyra border reaches a decent altitude in late evening. Thus, we will see the trailing edge of the shower this year. A waning gibbous Moon rises in the early morning hours, so the best time to view is between 10 P.M. and 2 A.M. local daylight time. Expect rates of around 20 meteors per hour but watch for unexpected outbursts.

## Moon feature: Pythagoras

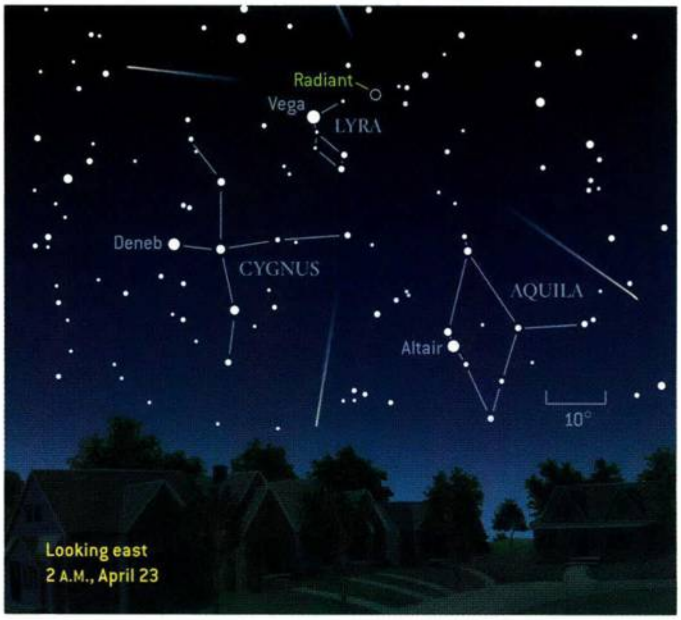
Lying close to the northwestern limb of the Moon, the crater Pythagoras appears quite prominent despite being a challenge to find. Located between the western shore of Mare Frigoris and the Moon's limb, Pythagoras sees the Sun rise a day or so before Full Moon — the best time to view the feature.

Pythagoras spans 80 miles (130 km), but its proximity to the limb means it appears highly foreshortened. The northern wall exhibits a polygonal outline, and the far walls are terraced and rise some 3 miles above the crater floor. The central mountain complex stands more than a mile high and, if you observe at the right time, its shadow will extend clear across the crater floor.

Full Moon occurs on April 16 at 3:36 P.M. EDT, so try to view this challenging crater on April 14 and 15. If you catch the crater just as the Sun rises over its walls, watch for a few hours — its appearance will change dramatically.



**THE CHALLENGING CRATER PYTHAGORAS** lies near the Moon's northwestern limb. Its terraced walls and central peak appear prominent just before Full Moon. FROM THE *CONSOLIDATED LUNAR ATLAS* (LPL/UA)



Looking east
2 A.M., April 23

## Jupiter's satellites

The occultations, eclipses, and transits involving the outer Galilean moon, Callisto, continue. During each 12-year orbit of Jupiter around the Sun, only two series of Callisto events occur. The current one began in late 2001 and lasts until September 2004. Events in the table are given in Universal Time and Eastern Standard Time (before April 6) or Eastern Daylight Time (after April 6).

Events that occur on either side of midnight are shown twice because the date changes between Europe and the United States. Tr = transit; I = ingress; E = egress; Oc = occultation; Sh = shadow transit; Ec = eclipse; D = disappearance; R= reappearance. The events are worth viewing due to their relative rarity.

/// APRIL CALLISTO EVENTS

| | { UT } | { ET } | { Event } |
|---|---|---|---|
| 2 | 13:59 | 8:59 | IV.Oc.D. |
| | 18:51 | 13:51 | IV.Oc.R. |
| | | 19:58 | IV.Ec.D.* |
| 3 | 0:58 | | IV.Ec.D.* |
| | 5:51 | 0:51 | IV.Ec.R. |
| 10 | 23:46 | 19:46 | IV.Tr.I. |
| 11 | 4:32 | 0:32 | IV.Tr.E. |
| | 11:08 | 7:08 | IV.Sh.I. |
| | 15:54 | 11:54 | IV.Sh.E. |
| 19 | 6:57 | 2:57 | IV.Oc.D. |
| | 11:49 | 7:49 | IV.Oc.R. |
| | 19:01 | 15:01 | IV.Ec.D. |
| | 23:54 | 19:54 | IV.Ec.R. |
| 27 | 17:13 | 13:13 | IV.Tr.I. |
| | 21:59 | 17:59 | IV.Tr.E. |
| 28 | 5:11 | 1:11 | IV.Sh.I. |
| | 9:55 | 5:55 | IV.Sh.E. |

*Events that occur on either side of midnight are shown twice.

# COMETS AND ASTEROIDS

As Comet C/2001 RX14 (LINEAR) starts to fade away in the evening sky, asteroid Vesta blazes forth as a naked-eye object.

**VESTA'S MOTION** against the background stars announces its presence to backyard observers. This pair of images shows the asteroid's motion through Gemini over nine days in 1977. PAUL AVELLAR

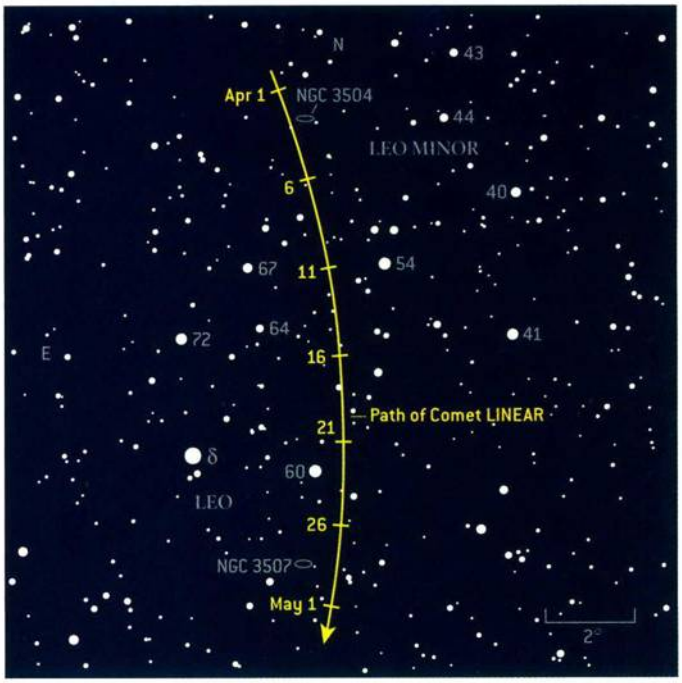
## A snowball on a lion

With spring now firmly in the air, Comet C/2001 RX14 (LINEAR) rises in the east along with Leo. All winter long, it lay in the morning sky, but as Earth arced gracefully around the Sun, the background constellations swung westward, pivoting the comet into view. RX14 (LINEAR) actually stays outside of Mars's orbit, which is why it has been visible for many months, like an outer planet.

Your best view of the comet will be from a dark country sky, free from moonlight and city lights. At 11th magnitude, RX14 (LINEAR) has a modestly low surface brightness similar to the many fainter galaxies that can be found on the Messier list. Next month it passes within a few degrees of the brighter galaxies M65 and M66.

During the dark of the Moon in early April, RX14 (LINEAR) remains less than 1° (a typical low-power telescopic field of view) from the spiral galaxy NGC 3504. By the end of April, the comet slides within a degree of NGC 3507, a face-on barred spiral.

In both cases, the comet should be about the same brightness as the distant galaxies. Take time to compare the pairs. All will have brighter cores and diffuse halos, but the comet should have a sharper edge. This comes from the solar wind blowing a bow wave around it.



## Vesta unaided in Virgo

If you've always wanted to see an asteroid with your naked eye, now's your chance. Thanks to its bright reflectivity, Vesta shines at 6th magnitude, well within reach of sharp-eyed observers from a dark site. With the snow gone and the fields plowed, spring usually brings some of the darkest skies of the year to temperate latitudes.

Once you memorize the star pattern of northern Virgo and let your eyes really dark-adapt, away from the glow of your red flashlight, you should be able to find the interloper. You might have to wait until midnight when it lies at its highest in the sky.

The 300-mile-wide (500-km) rock can be followed easily from the city with small binoculars. Start at Epsilon (ε) Virginis, jump one field of view to the upper right to reach Rho (ρ) Vir, then do one more hop in the same direction and you're pretty much there. For a detailed map and more tips on finding Vesta, see "Spot a naked-eye asteroid" on page 78.

Just for kicks, if you have an 8-inch or larger scope, point it at the Crab Nebula near Saturn on Saturday evening the 19th. Asteroid 44 Nysa will then be passing in front of the northern edge of this supernova remnant. At magnitude 11.3, Nysa could easily be mistaken for a background star — return after an hour to see if its motion betrays its identity. ■

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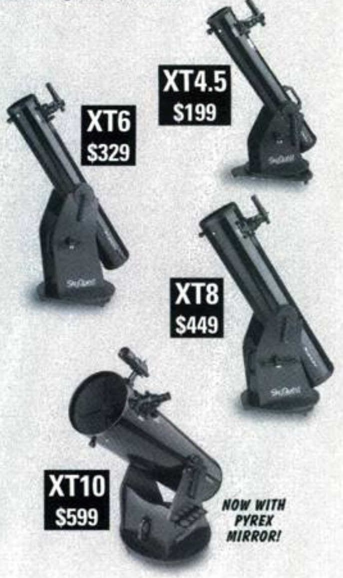

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## How do we know that the Milky Way Galaxy is traveling toward the Virgo Cluster at approximately 300 km/sec if there is nothing stationary to compare its motion to?

— **STEVE WILSON,** HEBRON, INDIANA

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When we look out to the surrounding distant galaxies and their clusters, we see them all moving away from us smoothly with speeds that are directly proportional to their distances. Double the distance, and you double the speed. At first it seems as if we are at the center of a gigantic expanding system, in which speeds increase at a rate of about 21 kilometers (13 miles) per second per million light-years' distance.

To produce the linear speed-distance relation, all galaxy clusters must be moving away from each other. As a result, we would witness the same thing no matter where we lived, and each galaxy would see itself at the center. In fact, there is no center, nor any edge, nor are the galaxies moving through space but along with space: Space is expanding, and the galaxies are going along for the ride.

This smooth expansion, however, is complicated by gravity. Within a cluster, galaxies orbit a common center of mass, so we see some of them going away from us a bit faster than the expansion rate predicts, others a bit slower. Close by, these gravitational movements compete with the expansion of space. Within our own little cluster they dominate, with some galaxies (such as M31 in Andromeda and M33 in Triangulum, as well as others) actually coming toward us.

Moreover, the massive Virgo Cluster exerts a gravitational pull on our own cluster, the Local Group. Virgo is actually moving away from us at a speed of about 1,100 kilometers (680 miles) per second. However, at Virgo's distance of about 60 million light-years, the velocity of recession predicted by the smooth expansion of the Universe may be as much as a couple hundred kilometers per second greater. Thus we are sometimes said to be "falling" toward the Virgo Cluster, but only in the sense that we are not moving away from it as fast as we would without Virgo's gravitational influence. — **JIM KALER,** UNIVERSITY OF ILLINOIS

**GALILEO'S TELESCOPES**

## What were the specs on Galileo's telescope, such as the aperture and eyepiece design? He recorded seeing the texture of the Moon as mirroring the texture of Earth. Realistically, what could he have seen with it?

— **SUSAN BERGER,** BERKELEY, CALIFORNIA

Only two of Galileo's telescopes, plus one cracked objective lens made by him, still survive. They are at the Institute and Museum of History of Science, in Florence, Italy (home page: galileo.imss.firenze.it/index.html).

In the early 1990s, three scientists (Vincenzo Greco, Giuseppe Molesini, and Franco Quercioli) tested the optics with modern lab equipment. They concluded that the lenses are well made, have a smoothly polished spherical figure, and approach being diffraction-limited. The biggest defect is chromatic

**GALILEO'S TELESCOPES** have been found to be exceedingly well made. Today, they reside in the Institute and Museum of History of Science, in Florence, Italy. BETTMANN/CORBIS aberration, unavoidable given that they are simple (single-element) lenses.

Telescope I (which consists of a paper-coated, longer tube) has a double-convex objective lens 51 millimeters in diameter and a focal length of 1,330mm. It is stopped down with a paper diaphragm to a clear aperture of 26mm; its f/ratio is f/51. With its plano-concave eyepiece lens, it magnifies 14x. Telescope II (made with a leather-coated, shorter tube) has a convex-plano objective 37mm in diameter and a focal length of 980mm. Its clear aperture is 16mm; the f/ratio is f/61. The original eyepiece lens is missing, and the double-concave one in the tube dates from an unknown later time. In any case, it gives Telescope II 21x magnification. The scientists also found that Galileo cut and placed the paper diaphragms so as to use the parts of the objective lenses that have the best figure.

The single lens, which accidentally broke in Galileo's lifetime, is 58mm in diameter and has a focal length of 1,710mm. In use it was stopped down to a 38mm aperture, yielding an f/ratio of f/45. It is not known what eyepiece Galileo used with it, but he used the single lens to discover the satellites of Jupiter.

Observing tests in 1923 showed that Telescope I has a resolution of 20 arcseconds, while Telescope II reaches 10 arcseconds. Both have a field of view about 15 arcminutes across. Since that's only half the Moon's diameter, using either telescope would be like looking through a soda straw. Obviously, modern instruments do much better. But Galileo's telescopes were certainly adequate to survey the lunar world and inspect craters, measure the heights of mountains, and so on, just as Galileo described in the *Sidereus Nuncius of 1610*. (See the translation by Albert van Helden.)

There's a curious sidelight. On December 28, 1612 and January 2, 1613, Galileo was observing Jupiter and logged a background star which was actually the planet Neptune, not discovered until 1846. The optics weren't sharp enough to reveal the planet's 2.3-arcsecond disk, yet Galileo noted that the star seemed to move a little between his observations. He took this as just an observational error, however, and didn't follow it up with further study.

Almost as spooky is the fact that another undiscovered planet, Uranus, lay less than 2° to the northwest of Jupiter during the first week of February 1610. This is when Galileo was deep in the Jupiter observations he reported in the *Sidereus Nuncius*. Uranus (discovered in 1781) was bright enough to be easily detected by the telescope, and its disk was 50 percent larger than Neptune's. The telescope's field was narrow, however, and Galileo was concentrating on Jupiter. So Uranus might as well have been on the other side of the sky. He never spotted it.

**ASTRONOMERS STUDY THE STRUCTURE OF SPACE-TIME** by observing light from distant objects like the galaxy NGC 4144. NASA, THE HUBBLE HERITAGE TEAM, STSCI, AURA

But you do have to wonder how the history of astronomy might have transpired if either Uranus or Neptune, or both, were discovered in the early 1600s. **— ROBERT BURNHAM**, CONTRIBUTING EDITOR

### GRAVITY AND LIGHT

**How can a massless thing like light be under the influence of gravity, which normally is the force between masses? — FREDERIC PETIT,** HOFFMAN ESTATES, ILLINOIS

It's precisely because the photon is massless that it can trace the structure of space-time. Light always travels by the most direct path (the one requiring the least work). In a simple, flat universe, this means a straight line in both space and time (no redshift, no bending). A more realistic universe, however, contains massive bodies such as stars and galaxies that influence the trajectory because of gravitation. As light works to get out of, or falls into, these gravitational "potholes," there's a change in its direction and frequency, both on the way into and out of the strongest parts of the field. This is the same as saying that the fabric of space-time curves due to the gravity of the bodies. In such a universe, beams of light again travel in the most direct path. Yet in this case the path of least action causes light's trajectory to bend because the most direct route is curved.

The only way we know the structure of the universe is through the propagation of light. It defines the geometry of the universe it's traveling through by the "straightness" of its path. **— STEVEN SHORE,** INDIANA UNIVERSITY, SOUTH BEND

THE GLORIOUS CONSTELLATIONS, © 1991; HENRY N. ABRAMS, INC.

# Centaurus and Antlia

Dip into the southern sky to sample some of these constellations' starry treats. /// BY TOM POLAKIS

The southernmost reaches of the Milky Way precede the arrival of the galaxy's center by several hours. The plane of our galaxy slices through the southern edge of Centaurus the Centaur, making one of the largest constellations also one of the starriest. Within its borders Centaurus holds more than 20 stars brighter than 4th magnitude. And along the galactic equator are the unmistakable stars Alpha (α) and Beta (β) Centauri, which form pointers to the adjacent constellation Crux.

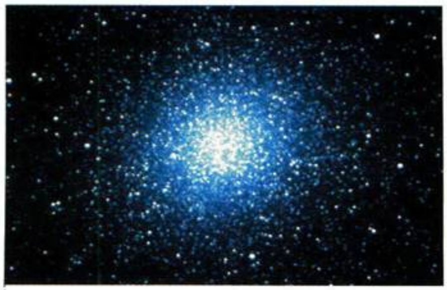
Alpha Centauri is arguably the most spectacular double star in the sky. It is certainly the brightest. With magnitudes of 0 and 1.3, the two components are currently separated by 12″. In the next 15 years, orbital motion will diminish this separation to 4″. The system's proper motion toward the west will carry it to within half a degree of Beta Centauri in 4,000 years, forming a spectacular close pair of bright stars. Beta Centauri is also a tight double star, with a 4th-magnitude component less than 1″ to the west.

Unfortunately, observers in the Northern Hemisphere get to see only about half of Centaurus. Most prominent is a large asterism that forms the shape of a "Y" when Centaurus culminates. The southern half of the constellation is dotted with nearby clusters and nebulae, while northern Centaurus is home to many bright galaxies.

In contrast, Antlia the Air Pump is small and sparse, containing only four stars brighter than 5th magnitude. Its brightest star, Alpha Antliae, has a spectral type of K4 and appears orange with unaided vision.

Located 40 million light-years away in the star-poor western side of Antlia is the bright galaxy **NGC 2997**. A 10-inch telescope shows an oval haze 5′ by 3′ elongated east-west with a much brighter core. In this aperture, spiral structure can be inferred from the brightness profile. A dark ring surrounds the core, and the arms look like a slightly brighter ring around the periphery.

In northern Antlia, **NGC 3175** is a nearly edge-on galaxy 50 million light-years from Earth. Visually, it appears three times as long as it is wide. It is quite faint and uniform across its nearly 3′ length.

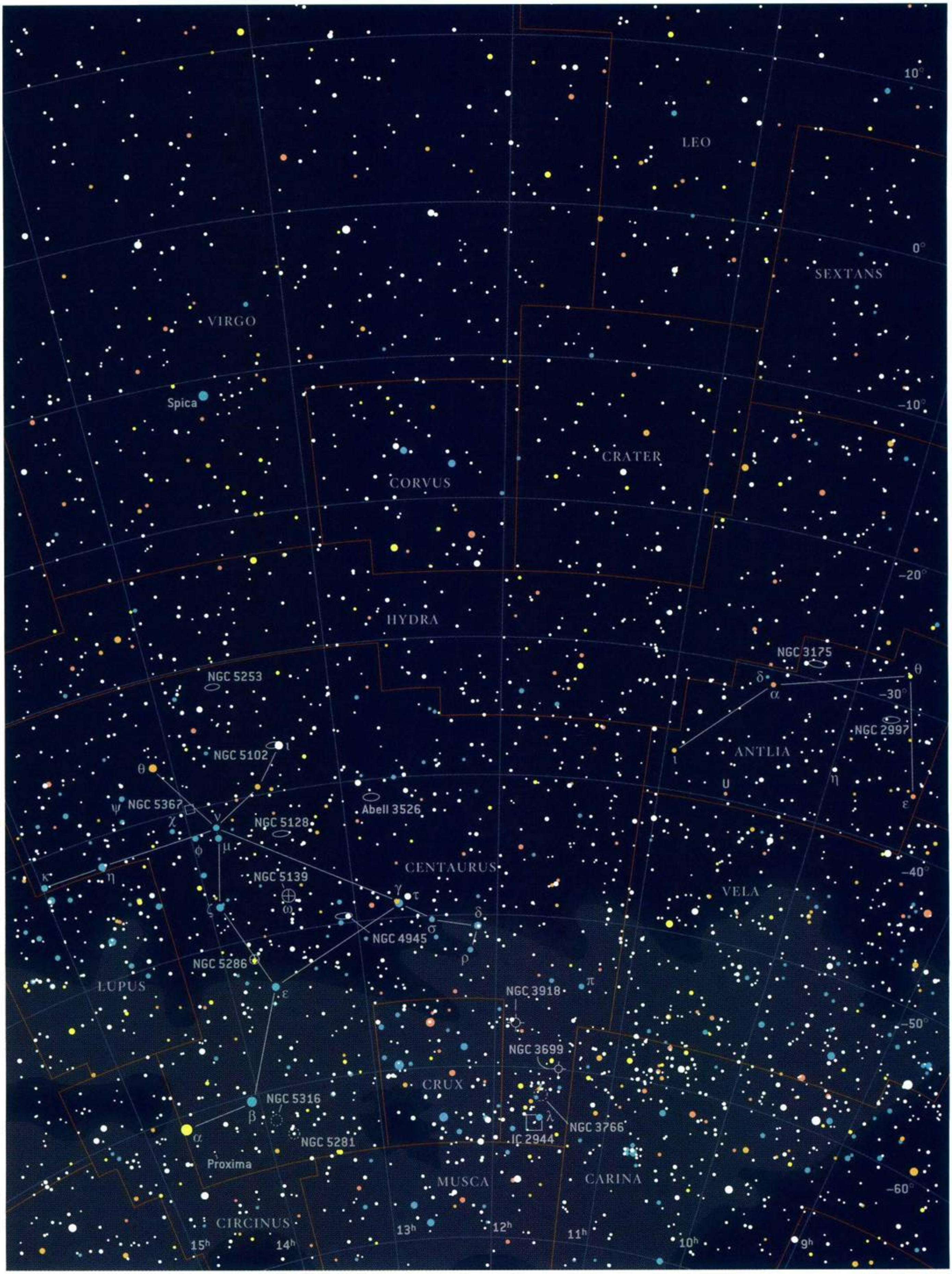


**OMEGA CENTAURI** lies 17,000 light-years from Earth and is the most massive globular cluster in our galaxy. SERGE BRUNIER

Before leaving Antlia for richer pastures, be sure to at least take a binocular glance at **U Antliae**, one of the sky's brightest carbon stars. It is a naked-eye star from dark sites, but its deep red color requires some optical aid to detect.

In the southwestern corner of Centaurus we find the bright emission nebula **IC 2944**. It fills an entire 1° field of view to the southeast of the 3rd-magnitude star Lambda (λ) Centauri, though the star and nebula are unrelated. IC 2944 is famous for the small dark nebulae discovered by David Thackeray in 1950, now known as Thackeray's Globules. They appear as shadows against the background HII region, which is 6,000 light-years away. Amateur telescopes fail to show these small clouds, but the HII region is bright in an 8-inch telescope equipped with a narrow-band nebula filter. Look a half degree southeast of Lambda Centauri to find a large, brighter V-shaped feature in a much fainter circular haze that is 1° in diameter.

Pan 1.5° north of Lambda Centauri to find the nice-looking open cluster **NGC 3766**. Seen from a distance of 7,000


10°
LEO
0°
SEXTANS
VIRGO
Spica
-10°
CRATER
CORVUS
-20°
HYDRA
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NGC 3766
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NGC 5281
IC 2944
Proxima
MUSCA
CARINA
-60°
CIRCINUS
15h
14h
13h
12h
11h
10h
9h

light-years, the full cluster occupies a diameter of 25 light-years. Within a diameter of 7′, you can glimpse 80 stars, mostly between magnitude 9 and 11. The aggregation is very pronounced, even against an already very rich field. At medium powers, a "spiral arm" of stars trails to the south away from the east edge of the core of the cluster. Nearly 300 cluster members have been counted in NGC 3766.

Moving farther north, we come upon the bipolar planetary nebula **NGC 3699**. Until recently, NGC 3699 was catalogued as an HII region due to its peculiar form. The nebula initially looks like a 1′ disk filled with fainter nebulosity. Deep images show widely separated upper and lower lobes. Using a 12-inch scope with a nebula filter, the two lobes are quite prominent, with the northern component appearing larger but fainter. "Blinking" the field with a nebula filter helps to find the fainter planetary nebula Sanduleak 2–76, 11′ to the southeast.

**NGC 3918** is a very bright planetary nebula easily found by following the stars in the shorter axis of Crux westward. Even small telescopes reveal the nebula's vivid blue-green color. The disk is about 10″ across and has a sharp edge. The central star hasn't been seen due to the high surface brightness of the nebula, but its magnitude is predicted to be 14.6.

Departing from these nearby objects of the Milky Way, **Abell 3526**, the Centaurus Galaxy Cluster, is home to hundreds of galaxies at a great distance from us. The galaxies in this single catalogued cluster actually belong to two superimposed clusters. One, called Cen 30, is centered on the brightest galaxy NGC 4696 and is 160 million light-years away. Cen 45 is centered on NGC 4709 at a distance of 220 million light-years. NGC 4696 is elongated east-west and is roughly 1.5′ long. Fifteen arcminutes to the east, NGC 4709 is circular and 1′ across with a bright core. A 20-inch telescope will show the brightest couple dozen members of the cluster. Faint galaxies can be found across the cluster's full 3° span.

Pan 4° east of Gamma (γ) Centauri to find **NGC 4945**, a barred spiral galaxy whose central region is bursting with star formation. A 10° tilt keeps NGC 4945 from being edge-on, and distance estimates to the galaxy range from 12 to 22 million light-years. Telescopically, this is a bright galaxy, spanning 15′ by 3′. The surface brightness is mostly uniform, but it fades and tapers, especially at the southwestern end. Near the northern end is a dark feature that shows up as an extension of the dust lane in long-exposure images. A rich foreground peppered with stars enhances the scene.

**Omega Centauri (NGC 5139)** is unquestionably one of the two most spectacular globular clusters (along with 47 Tucanae, which also resides in the deep southern sky). Northern observers can find it by following a long chain of stars southward from Spica, but southern observers have the luxury of using Alpha and Beta Crucis as pointers. Starhopping is not even necessary, though, as the globular is distinctly fuzzy to the naked eye. Even in instruments with just 3 inches aperture, the cluster's brightest stars begin to resolve. Its true form shows up in scopes 6 inches or larger, where it is a completely resolved globe of stars. The full size is nearly 1°, and amateur instruments show fields close to this diameter. Note the low degree of concentration; at magnifications above 150, it looks like a rich star field with no apparent center.

Omega Centauri's 3 million solar masses make it the most massive globular cluster in the Milky Way. It may be the core of a dwarf elliptical galaxy whose outer envelope has been disrupted. Due to rotation, Omega Centauri takes on an oblate form, which is quite noticeable in backyard scopes at low magnifications.

Now pan 4.5° north to find an equally interesting object: the giant elliptical galaxy **NGC 5128**. At a distance of only 11 million light-years, it is also a nearby member of its class. NGC 5128 was a normal elliptical until it accreted a small galaxy. The remains of this encounter present themselves in the form of a dust

### /// Deep-Sky Objects in Centaurus and Antlia

| OBJECT | R. A. | DEC. | MAG. | SIZE | TYPE | NOTES |
|---|---|---|---|---|---|---|
| NGC 2997 | 9h45.6m | –31°11′ | 9.3 | 10.0′ by 6.3′ | Gal | SAB(rs)c |
| NGC 3175 | 10h14.7m | –28°52′ | 11.3 | 5.0′ by 1.3′ | Gal | SAB(s)a |
| U Antliae | 10h35.2m | –39°34′ | 5.4 | — | Star | Carbon star |
| NGC 3699 | 11h28.0m | –59°57′ | 11.3 | 67″ | PN | |
| NGC 3766 | 11h36.1m | –61°37′ | 5.3 | 12′ | OC | |
| IC 2944 | 11h38.3m | –63°22′ | — | — | BN | |
| NGC 3918 | 11h50.3m | –57°11′ | 8.1 | 12′ | PN | |
| Abell 3526 | 12h48.9m | –41°18′ | — | 180′ | Gals | Centaurus Cluster |
| NGC 4945 | 13h05.4m | –41°18′ | 8.8 | 23.0′ by 5.9′ | Gal | SB(s)cd |
| NGC 5102 | 13h22.0m | –36°38′ | 8.8 | 9.8′ by 4.0′ | Gal | SA0 |
| NGC 5128 | 13h25.5m | –43°01′ | 6.7 | 31.0′ by 23.0′ | Gal | Centaurus A |
| NGC 5139 | 13h26.8m | –47°29′ | 3.5 | 36.3′ | GC | Omega Centauri |
| NGC 5253 | 13h39.9m | –31°39′ | 10.2 | 5.1′ by 1.3′ | Gal | Im pec |
| NGC 5286 | 13h46.4m | –51°22′ | 7.2 | 9.1′ | GC | |
| NGC 5281 | 13h46.6m | –62°54′ | 5.9 | 5′ | OC | |
| NGC 5316 | 13h53.9m | –61°52′ | 6.0 | 13′ | OC | |
| NGC 5367 | 13h57.7m | –39°59′ | — | 2.5′ by 2.5′ | BN | |
| Proxima Centauri | 14h29.7m | –62°41′ | 11.0 | — | Star | Nearest star |

**Object:** Designation in NGC or other catalog. **R. A. and Dec.:** Right ascension and declination in epoch 2000.0 coordinates. **Mag.:** Visual magnitude. **Size:** Size in arcminutes or arcseconds. **Notes:** Hubble types for galaxies.

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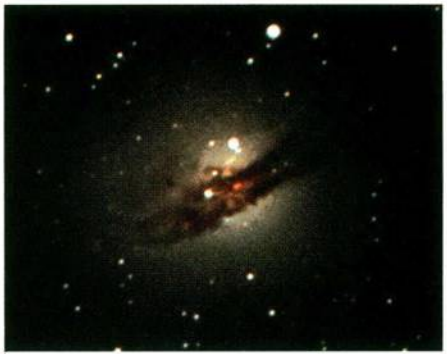
**Tom Polakis** *lives in Tempe, Arizona, and enjoys deep-sky observing and astrophotography.*



**NGC 5128** is a nearby active galaxy. Also known as Centaurus A, it is an intense radio and x-ray source. KEN AND MATT BLANKENSHIP

**NGC 2997** lies 40 million light-years away in Antlia. The spiral galaxy contains a ring of nine hot spots of star formation. ANDREW PETERS

**NGC 4945** is a nearly edge-on, barred spiral galaxy in Centaurus and features a dark, dusty lane. ANDREW PETERS

lane that traverses the minor axis. This galaxy is prominent at radio wavelengths, earning the designation Centaurus A.

In a 12-inch telescope, NGC 5128 immediately shows a circular haze 8′ across divided by a dark lane 1′ wide. A closer look shows that the lane widens slightly at the ends. A thin dagger of light shines through the lane on its western end. By backing off the power, we find that the bright central region has extensions to the northeast and southwest perpendicular to the dust lane, bringing the size to nearly 15′ long. Look for a 12th-magnitude star superposed on the northwestern end of the dark lane.

NGC 5128 heads a galaxy group that includes the spiral **NGC 5102**. Due to its proximity, this low-luminosity galaxy is moderately bright. It covers 5′ by 2′ and has a much brighter core highlighted by a stellar nucleus. Use medium magnification to keep the glare of Iota (ι) Centauri out of the field.

At the northern edge of Centaurus is the peculiar dwarf galaxy **NGC 5253**. Despite its proximity (11 million light-years), details are elusive. At the center lies a star cluster that's only 150 light-years across but contains hundreds of thousands of stars — enough to illuminate a surrounding "supernebula." Astronomers believe NGC 5253 may have been a dwarf elliptical galaxy until an ancient encounter with M83, currently less than 2° to the north. In an 8-inch scope, the dwarf appears bright and 6′ long with a much brighter center. A 13-inch telescope reveals several knots across the face with the brightest at the northeastern end.

Return south to the bright reflection nebula **NGC 5367**. In a 10-inch telescope, an evenly illuminated haze 3′ across surrounds an associated 9th-magnitude star. To the northeast is a detached 2′ by 1′ region. Deep images show structure reminiscent of the Pleiades nebulosity.

The globular cluster **NGC 5286** could easily be passed over were it not for the presence of a brilliant field star. With its brightest star at magnitude 13.5, this cluster resolves with some difficulty in backyard scopes. The apparent size is about 3′, and a sprinkling of stars can be seen around a well-concentrated center. Only 4′ from the center is M Centauri, a yellow spectral type G9 star of 5th magnitude. At a distance of 48,000 light-years, NGC 5286 is nearly 200 times as distant as the intervening star.

Now we move into the very busy southeastern corner of Centaurus to find the compact open cluster **NGC 5281**, lying 4,300 light-years away. Fifty stars between 10th and 13th magnitude are crowded into a region 5′ across. A 7th-magnitude star lies just north of center. Away from this star, the cluster members seem to be organized in small clumps.

A small, 1.5° pan to the northeast brings into view a similarly distant open cluster, **NGC 5316**. It presents 40 stars between 11th and 13th magnitude clustered into an 8′ diameter. The stars are not well detached from a very rich Milky Way field.

We finish with the closest star, **Proxima Centauri**. At a distance of 4.22 light-years, it is only 0.17 light-years closer to us than its neighbor, Alpha Centauri. However, it shines at only 11th magnitude and is easily missed. A star-hop should begin with its companion Alpha Centauri, just over 2° north-northwest. The Sun is 20,000 times as luminous as this red dwarf.

### /// THE CENTAUR

*Over the hill the centaur goes,*
*round the mountain and back again,*
*a little too far from the world of dreams,*
*and just beyond the world of a man.*
*The Centaur, Shel Silverstein (1930-1999)*

**The clan of half-man, half-horse beasts** of Greek mythology have two representatives among the stars. Although not all tales agree on the identity of the centaur represented by Centaurus, most see the constellation as the wise and benevolent Chiron. Unlike warring Sagittarius and the other centaurs, who were said to be typically violent, disagreeable, and untrustworthy creatures, gentle Chiron was educated and skilled in a variety of fields, including astronomy and medicine. He was an esteemed teacher who tutored many Greek heroes, including Hercules.

One day, during a skirmish over a communal bottle of wine Hercules had opened without permission from the centaurs, Hercules accidentally shot Chiron with a poisoned arrow. Immortal and unable to die, Chiron was in terrible pain. Despite his medical lessons, Hercules was unable to heal his teacher. He pleaded with the god Zeus to have mercy and allow Chiron to die. (Some variants say Hercules bargained to have Chiron's immortality traded to rescue Prometheus, who was being punished for stealing fire from the gods and giving it to humans.) Zeus agreed and honored Chiron by placing his likeness among the stars. — *Vanessa Thomas*

## PLANETARY OBSERVING

Finding Vesta with the naked eye is a challenge that any backyard observer can meet. /// BY RICHARD TALCOTT

# Spot a naked-eye asteroid

You can count the number of solar system objects visible to the naked eye on the fingers of your two hands. Not counting the occasional bright comet, the total comes to ten — and that includes both the Sun and Earth, objects not traditionally revered by backyard observers. The Moon, Venus, Mars, Jupiter, and Saturn are usually easy to spot. Mercury has a reputation for being elusive because it normally lies in twilight, but it's bright and fairly simple to see if you know where to look. And Uranus, although by no means bright, stays above naked-eye visibility most of the time.

That leaves the asteroid Vesta. This chunk of rock, just 335 miles in diameter, lies between the orbits of Mars and Jupiter. It never glows brightly, and even eagle-eyed observers have no hope of spotting it most of the time. But during March and April, almost anyone with access to dark skies and a desire to see Vesta has a good shot.

The favorable circumstances arise because Vesta reaches an excellent opposition on March 26. On this date it lies opposite the Sun in our sky, rising at sunset, lying highest in the sky around local midnight, and setting as the Sun rises. Opposition also marks Vesta's closest approach to Earth, so it reflects more sunlight in our direction and appears brighter than usual.

At opposition, Vesta lies among the background stars of Virgo the Virgin and glows at magnitude 5.9, making it some 75 percent brighter than a 6.5-magnitude object (usually considered the limit of naked-eye visibility). And it remains brighter than magnitude 6.5 throughout March and April. That doesn't mean it will be easy to see — just that it comes within the realm of possibility.

The key is to find an observing site far removed from the lights of the city. If you don't have a dark sky, you'll lose the fainter stars and Vesta along with them. A dark sky also means a moonless sky. Avoid trying for Vesta when the Moon is more than half-lit. This year, that coincides with the middle two weeks of both March and April.

Start your quest by finding the 2nd-magnitude star Denebola, which marks the tail of the constellation Leo the Lion. The circular star map at the center of the magazine will help you locate this signpost, which lies roughly 10° to the north-

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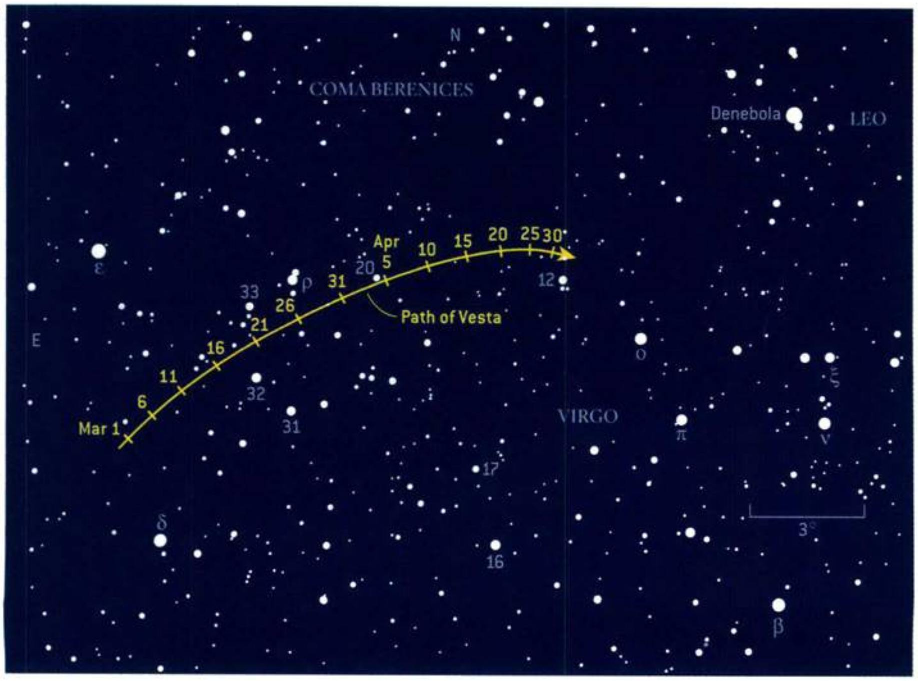
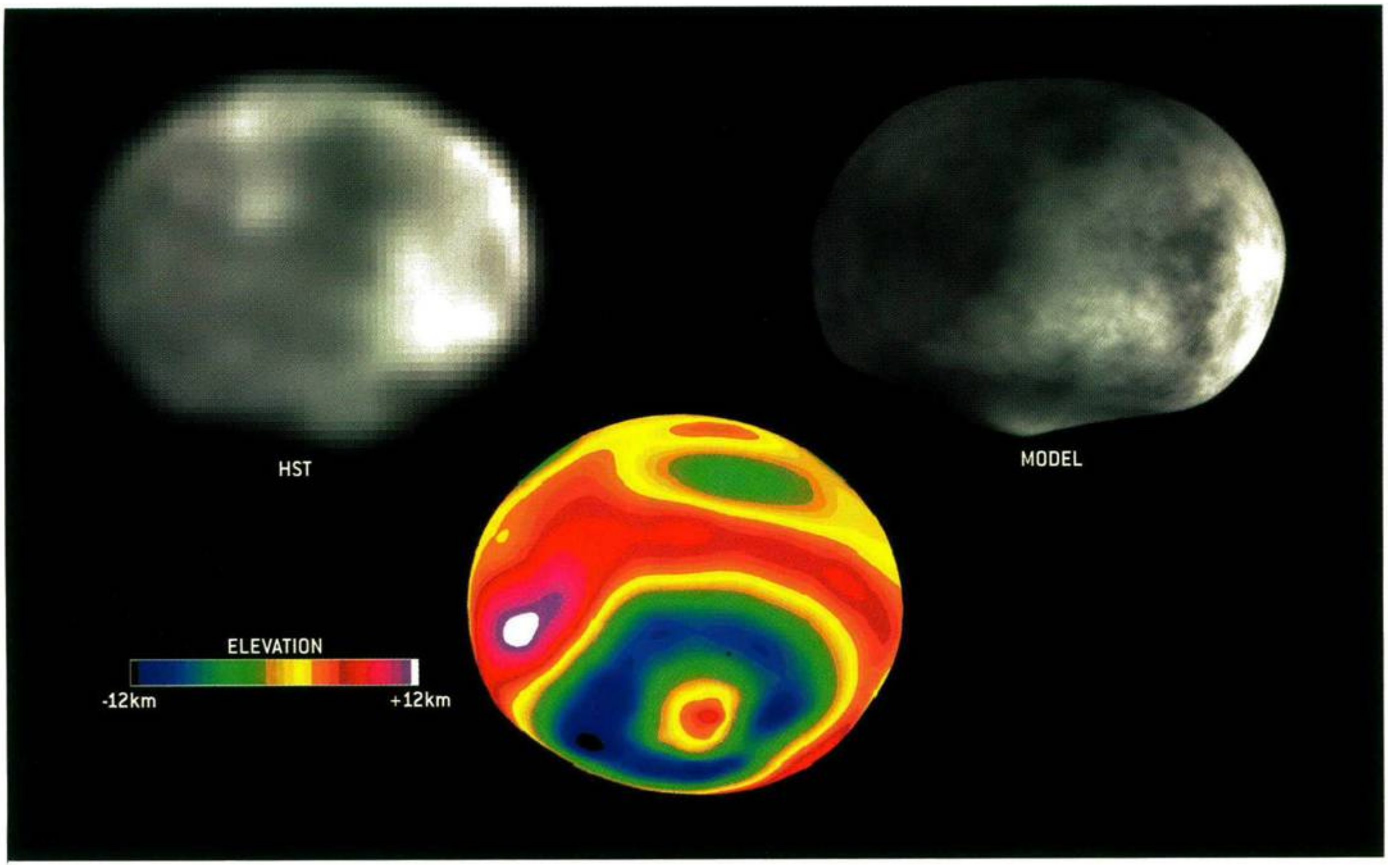
**Richard Talcott** *is senior editor of* Astronomy.



**/// POSITIONS OF VESTA**

| Date | R. A. | Dec. | Mag. |
|---|---|---|---|
| March 1 | 12h59.0m | 6°03' | 6.3 |
| March 6 | 12h56.6m | 6°41' | 6.2 |
| March 11 | 12h53.5m | 7°20' | 6.1 |
| March 16 | 12h49.8m | 7°59' | 6.0 |
| March 21 | 12h45.7m | 8°37' | 5.9 |
| March 26 | 12h41.2m | 9°13' | 5.9 |
| March 31 | 12h36.6m | 9°46' | 5.9 |
| April 5 | 12h32.1m | 10°13' | 6.0 |
| April 10 | 12h27.6m | 10°36' | 6.0 |
| April 15 | 12h23.6m | 10°51' | 6.1 |
| April 20 | 12h20.0m | 11°01' | 6.2 |
| April 25 | 12h16.9m | 11°03' | 6.3 |
| April 30 | 12h14.5m | 10°59' | 6.4 |

**R. A. and Dec.**: Right ascension and declination in epoch 2000.0 coordinates.
**Mag.**: Visual magnitude.



**A MODEL OF THE ASTEROID VESTA** (above right) is compared with a NASA/ESA Hubble Space Telescope image (above left), taken in May 1996 at a distance of 110 million miles from Earth. **A COLOR-CODED ELEVATION MAP,** constructed from 78 Wide Field Planetary Camera 2 pictures, illustrates Vesta's giant 285-mile-diameter impact basin and "eye" central peak. BEN ZELLNER (GEORGIA SOUTHERN UNIVERSITY), PETER THOMAS (CORNELL UNIVERSITY), AND NASA

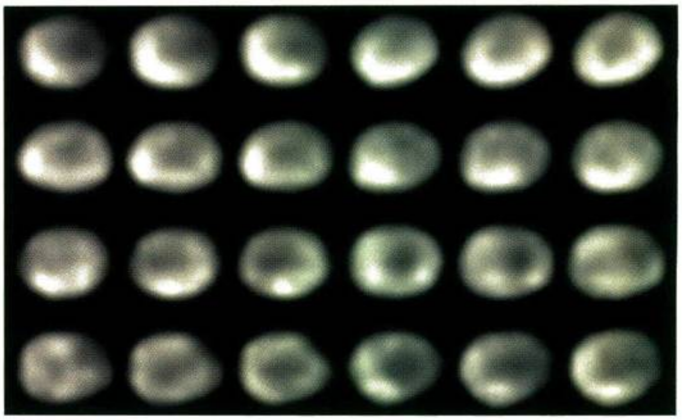
west of Vesta's position throughout the current apparition.

Next, zero in on Vesta with the help of the finder chart (opposite page). The chart shows Vesta's position during the evening hours in North America. (For observers in Europe, that corresponds to the morning hours of the following day.) During early March, Vesta lies about one-third of the way between the 3rd-magnitude stars Delta (δ) and Epsilon (ε) Virginis. By the time of opposition, it skims just 1° south of 5th-magnitude Rho (ρ) Virginis. It continues to head west through Virgo during April, providing several more good observing opportunities during the month.

The chart shows stars down to magnitude 8.5, so you should be able to pick out Vesta easily from the background stars. If you have trouble, try to find it first with binoculars. Once you spot it with those, it shouldn't be too hard to see with the naked eye.

After following these tips for spotting Vesta, you'll be well on your way to seeing all ten of the brightest solar system objects, or, perhaps, already there. It's a challenge for any backyard observer, beginner or experienced, to aspire to. ■

**VESTA SENT EARTH** a sample of its crust in the form of a meteorite. Scientists have confirmed samples from only two other solar system objects: Mars and the Moon. R. KEMPTON (NEW ENGLAND METEORITICAL SERVICES)



**A SERIES OF 24 IMAGES** taken by the Hubble Space Telescope shows the full 5.34-hour rotation of Vesta, which is 325 miles in diameter.
B. ZELLNER (GEORGIA SOUTHERN UNIVERSITY) AND NASA

## ECLIPSE CHASING

Lively kangaroos, lethargic koalas, and a luminous corona highlighted our Australian eclipse adventure. /// BY RICHARD TALCOTT

# Darkness Down Under

The night seemed endless. As the plane took off from Los Angeles in the early evening and flew west, the Sun had to work overtime to catch up. Some passengers passed the time sleeping fitfully, while others kept an eye on the Qantas movie marathon. But no one could sleep the whole night through — we were all too excited about our impending two-week adventure in Australia. The highlight promised to be a spectacular view of the December 4 total solar eclipse. Although the eclipse offered just 33 seconds of totality, it also provided the last, easily accessible eclipse track until 2006. With that incentive, two weeks and thousands of dollars seemed a small price to pay for the nearly 40 people who joined *Astronomy* magazine and Specialty Tours for the journey Down Under.

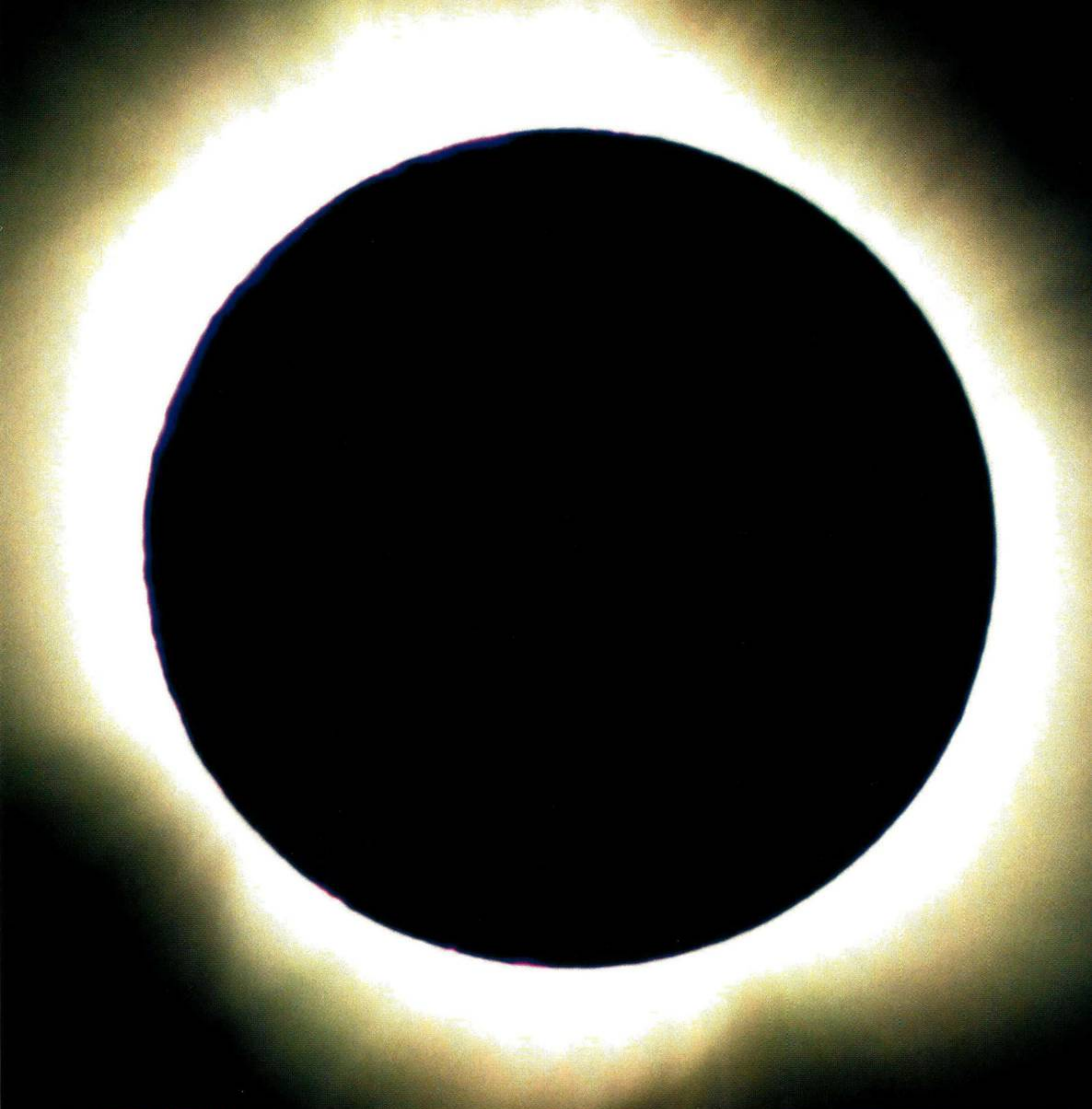
Our first full day in Australia found us literally "down under." Our base of operations was Cairns (pronounced "cans" by the locals) in Queensland, gateway to the Great Barrier Reef. A 90-minute boat ride took us to a pontoon anchored next to the outer reef, where we spent much of the day snorkeling and trolling in a semi-submersible, mesmerized by the colorful fish, giant clams, and coral formations that form the largest living structure on the planet.

**CLOUDS SWEPT ACROSS THE SUN** less than 15 minutes before totality, but by this point we were pretty confident that the totally eclipsed Sun would find a clear patch. JOHN DEWAN

The Cairns area boasts two World Heritage Sites, and the next day found us exploring the second: the tropical rain forest near Kuranda. Two years of severe drought have taken their toll on the normally lush forest, where tinder-dry undergrowth is now the norm, and raging waterfalls have been reduced to trickles. Yet it was still impressive, and it gave us our first opportunity to view exotic animals found nowhere else in the wild. Kangaroos, koalas, and wombats vied for our attention with vibrant butterflies and multihued birds.

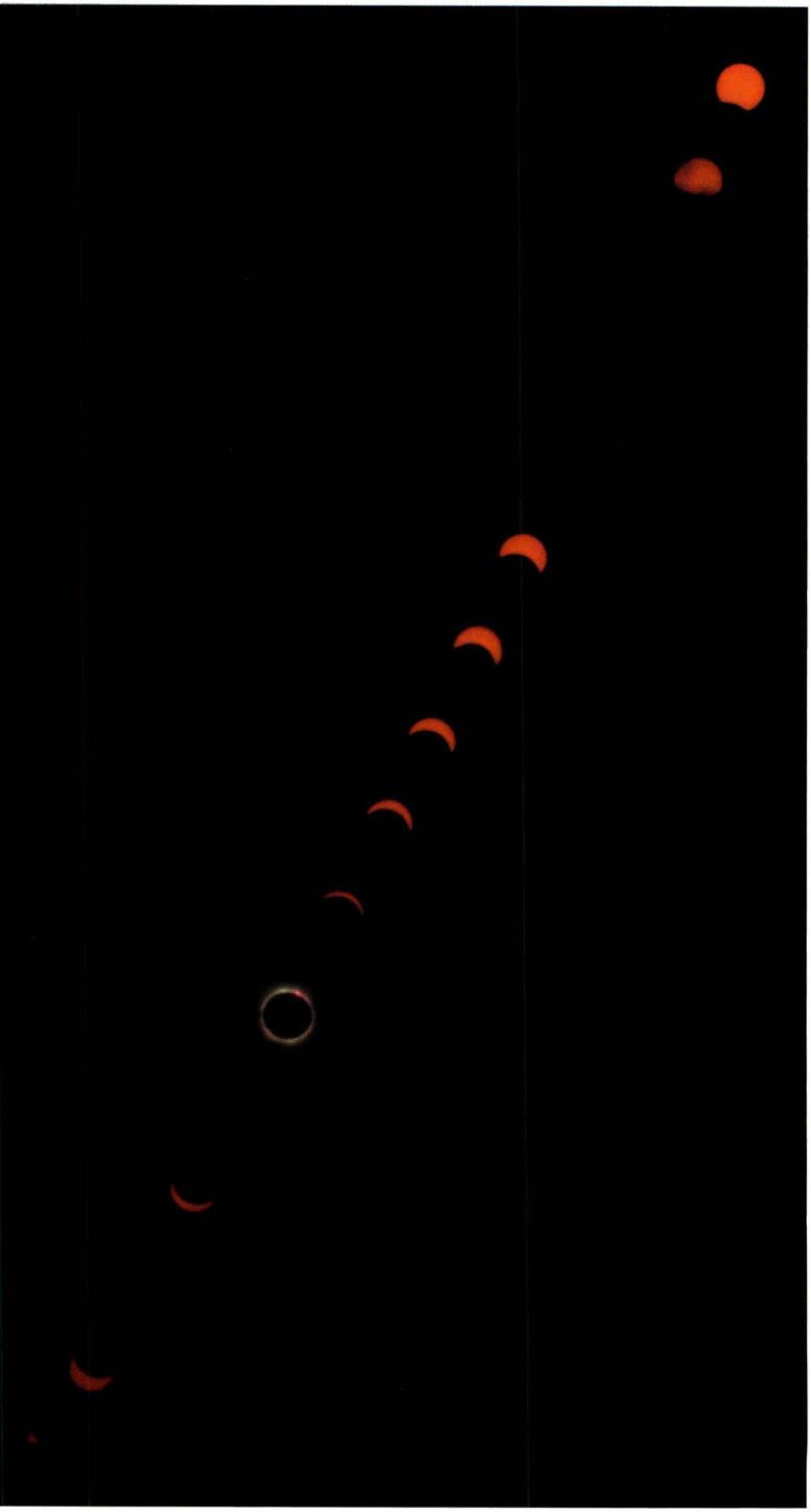
After Cairns, we flew south to Sydney, the site of the first English settlement on the continent. With 4 million people, Sydney ranks as the country's largest city, and a familiar one to many Americans since it hosted the 2000 Summer Olympics. The Sydney Opera House and Harbour Bridge were within easy walking distance from our hotel, as was the Old Sydney Observatory. During an evening tour of the observatory, we saw lots of old equipment, including the original transit telescope used to determine the time of day, although our view of the sky was hampered by city lights and clouds left over from an afternoon downpour. Our three-day stay in Sydney also left plenty of time for shopping, sightseeing, and a cruise of the magnificent harbor.

Next on the itinerary was Melbourne, the capital of Victoria. In three days there, we visited the Old Melbourne Observatory, the Scienceworks Museum and Planetarium, and the Swinburne Centre for Astrophysics and Supercomputing, whose staff treated us to a full morning of talks and demonstrations.



**A GLORIOUS CORONA** greeted observers along much of the path of totality on December 4. This view from southern Africa nicely captures the Sun's tenuous outer atmosphere, revealing its generally uniform appearance. TONY HALLIDAY

**SYDNEY'S ICONIC OPERA HOUSE** stands on the water's edge, across Circular Quay from our hotel in the Rocks section of the city. EVELYN TALCOTT



**WAITING WAS THE ORDER OF THE DAY,** as we arrived at our eclipse site in Ceduna more than six hours before first contact. JOHN DEWAN

Yet the highlight of our stay was a trip to the dark-sky site of the Astronomical Society of Victoria, located an hour and a half north of Melbourne. Half a dozen society members brought their telescopes along to show us the treasures of the southern sky. While Alpha and Beta Centauri and Crux the Southern Cross were scraping the horizon, the Large and Small Magellanic Clouds stood high in the south. We got spectacular views of the Milky Way's companion galaxies, including the Large Cloud's Tarantula Nebula — the biggest and brightest emission nebula known in the universe. We also saw our galaxy's finest nebula, Eta Carinae. These sights, along with those of the magnificent globular cluster 47 Tucanae, several brilliant open clusters, numerous double stars, and other impressive galaxies, made us northerners envious. And while it's disorienting to see Orion standing on his head, the Hunter cuts an impressive figure regardless of the hemisphere.

As we drove back to Melbourne late that night, we happened on a family of kangaroos in the middle of the dirt road. The youngest 'roo seemed transfixed by the bus's lights. Whenever we moved forward, it hopped along in front of us. When we stopped, it nervously rested — always in the middle of the road. This game of cat and mouse lasted a good

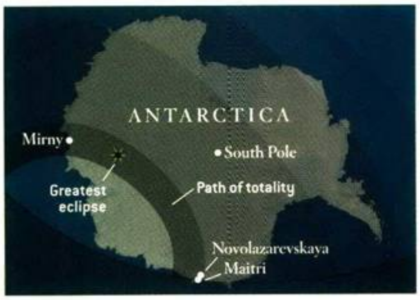
**A SEQUENCE OF ECLIPSE IMAGES** taken every five minutes shows the intermittent clouds our group had to contend with. DAVID BARSTOW

**A BRILLIANT DIAMOND RING** signaled third contact and the end of the brief total eclipse, seen here from inland Australia. JOEL HARRIS

## /// AN ECLIPSE WAY DOWN UNDER

If Australia whetted your appetite for more — or you just want to see what all the hoopla's about — you have another chance to see a total solar eclipse late this year. On November 23, the Moon will pass directly in front of the Sun, blocking its bright photosphere from view and revealing the majestic corona. At maximum eclipse, the Sun will disappear for nearly two minutes, nearly four times as long as in Australia this past December.

That's the good news. The bad news: If you think a trip to Australia is tiring, just wait until you arrive in Antarctica. The November 23 eclipse cuts a 300-mile-wide path across the frozen continent, passing over three Russian coastal research stations (Mirny, Maitri, and Novolazarevskaya) and little else. The interior of the continent offers better prospects for clear skies, but at the expense of temperatures that will likely dip well below freezing. If an eclipse adventure is what you really crave, you need look no further. — *R. T.*



**EXOTIC WILDLIFE** makes Australia a naturalist's dream. (Clockwise from top left) Among the species we saw were the cuddly koala, a school of fish at the Great Barrier Reef, a colorful butterfly, and the endangered cassowary. KOALA: DAVID BARSTOW; OTHERS: EVELYN TALCOTT

five minutes before the youngster finally darted into the woods.

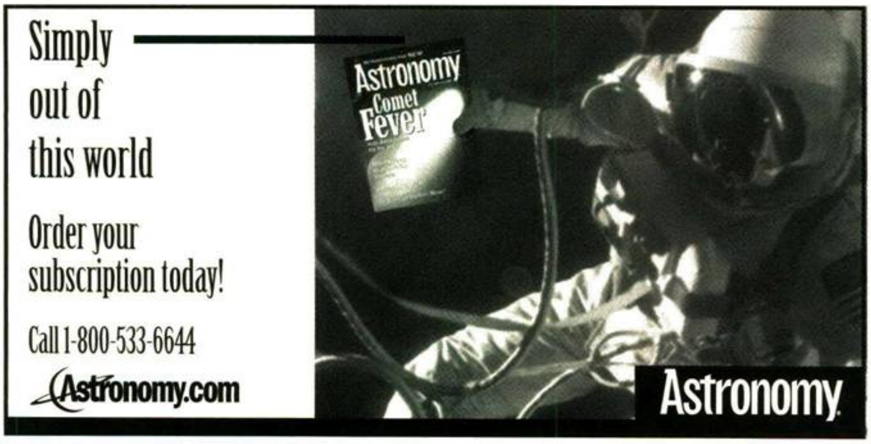
After Melbourne, we flew to Adelaide and boarded buses for the trek to our eclipse site in the small coastal town of Ceduna, located on a bay of the Indian Ocean known as the Great Australian Bight. The long ride was broken by a night's rest, with some of us staying in the town of Kimba and others in Wuddina. The day of the eclipse dawned cloudy, and a few drops of rain hit the bus windows as we prepared to leave. But intermittent patches of blue sky convinced us that we had a good chance to see totality, so we pressed on.

Once we arrived at our reserved site on the centerline in Ceduna, we realized that our biggest problem would be the wind. The unrelenting, 40-mile-per-hour gale brought an unexpected chill to the air — and would play havoc with attempts to take close-up photos of the eclipsed Sun. The long afternoon brought off-and-on clouds, with our hopes waxing and waning in tandem. First contact arrived precisely at 6:40 P.M. — but we missed it in the clouds. The Sun returned to view shortly after, although we kept losing it intermittently for the next 50 minutes as the Moon climbed slowly to meet the Sun. Ten to 15 minutes before third contact, the crescent Sun appeared faintly through thin clouds. But, just as predicted, the cumulus clouds were dissipating as the Sun's heat diminished, and it looked like the Sun would hit a clear patch by totality.

It did. The estimated 15,000 people along the foreshore started whooping as the last vestiges of sunlight disappeared. Our friendly star had been transformed, with its ghostly corona radiating from a hole in the sky. A bright prominence leaped from the limb of the Sun, which stood just 10° above the ocean.

The diamond ring that marked the end of totality came much more quickly than any of us had anticipated — surely the fastest 33 seconds of our lives. The clouds returned before the Sun set, but by then none of us much cared: We saw what we had come to see.

The eclipse served as an exclamation point for a fabulous trip. But the journey had us wondering when we would see totality again. Would we brave the cold of Antarctica in 2003? How about a long, Pacific Ocean cruise for 42 seconds of totality in 2005? Or, more likely, will we wait until 2006 to see a 4-minute eclipse that crosses Africa, the Mediterranean, and Asia? Whatever any of us decides, it will seem a long time to wait. ◼



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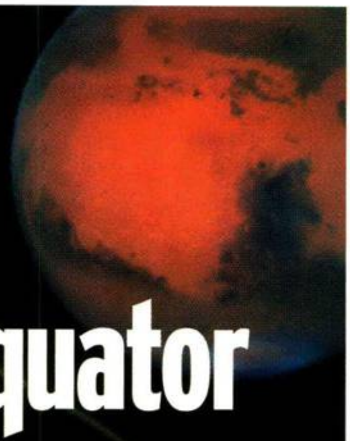

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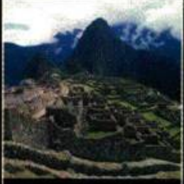

The Lost City of the Incas, discovered in 1911 at an elevation of 7,872 feet, is one of the most-sought special locations on the planet. Most of the thousands of visitors will leave by 5 P.M.; our group will camp under the stars at this legendary site.

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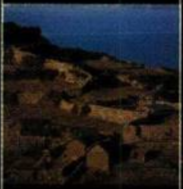

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## TECHNIQUES

Sirius Optics' VFS-1.25 houses a complete filter system in a single unit. /// BY PHIL HARRINGTON

# All-in-one filter system

Most experienced observers agree that using color filters brings out subtle highlights in the planets. Until now, amateurs have had to buy several filters, since different colors enhance different features. Using multiple filters presents the inconvenience of attaching and detaching filters, which will often jostle and move the target out of view.

**SIRIUS OPTICS' VFS-1.25** is contained in a sleek, black, aluminum shell and offers an efficient alternative to transporting numerous filters to an observing site.

Taking a unique approach, Sirius Optics of Kirkland, Washington, recently introduced the "Variable Filter System," or VFS-1.25. Rather than using one color filter at a time, the VFS-1.25 is an enclosed filter assembly that inserts into a telescope's focuser. Eyepieces, in turn, slip into the VFS-1.25's eyepiece tube and are locked in place with a single thumbscrew. Inside the black-anodized housing, a piece of optical glass measuring 71mm across has been coated with different thin films to produce varying filtering factors (technically speaking, bandpass frequencies) and mounted in a rotating metal ring. The VFS-1.25's colors are far subtler than typical color filters, yet results are quite distinctive.

To change from one color to the next, an observer simply has to rotate the section of the filter's metal ring that protrudes from the side of the housing, then watch through the eyepiece as the target changes shades from red to green, yellow, orange, magenta, and all colors in between. Keep turning the wheel to see the changing effects that different colors have on an object and stop whenever you want. That's all there is to it.

I tested the VFS-1.25 filter using my 8-inch f/7 and 18-inch f/4.5 Newtonians, as well as my 4-inch f/9.8 refractor. Observers should note that since the filter fits between the focuser and the eyepiece, the eyepiece protrudes about 1.5 inches farther out of the focuser than it would without the filter in place. Because of this, a focuser with limited inside-

Sirius Optics
Variable Filter System
VFS-1.25

**THE VARIABLE FILTER SYSTEM,** joined with a star diagonal, 40mm Plössl eyepiece, and 8-inch SCT allows observers to view delicate planetary highlights.

SIRIUS OPTICS
VARIABLE FILTER SYSTEM
VFS-1.25

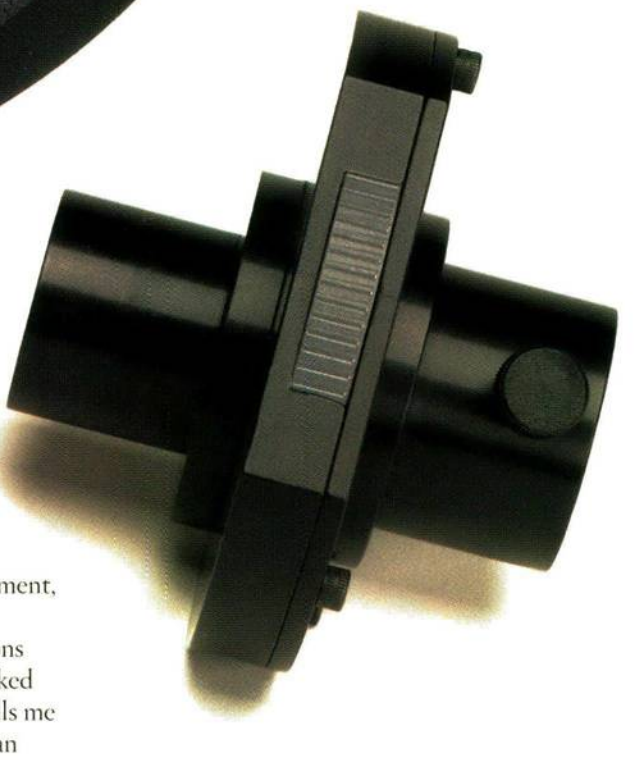
focus travel will not be able to bring the eyepiece in close enough to focus. That problem is most easily remedied by inserting a shorty Barlow lens between the focuser and filter. Of course, doing so will increase magnification accordingly. Although I was unable to focus non-Barlowed images through my 18-inch reflector with the filter in place, my 8-inch reflector, with its greater focuser range, had no trouble. The refractor without a Barlow could also focus images, as long as the star diagonal was removed.

My first stop with the filter was Jupiter, which presented an interesting change in appearance as I slowly turned the filter wheel. I preferred the view from the filter's yellow-orange range, where there was a noticeable improvement in the contrast of the atmospheric belts. However, the remaining variations had something to offer. Subtle features, including several cloud swirls and dark markings, were invisible without a filter. Saturn also showed improvement, although it was more modest than Jupiter. In both cases, magnifications between about 120x and 200x worked best. Al Misiuk of Sirius Optics tells me their filter will also enhance martian detail, although the Red Planet was too far away (and hence, very small) at the time for me to run a valid check. Venus showed no appreciable change for the better with the filter, apart from suppressing glare slightly.

Unfortunately, the wheel on the unit I tested was not marked with a scale, which made it impossible to reset the filter to an exact setting. Sirius Optics promises that a graduated scale is a planned improvement for future units — a welcome addition.

The Sirius Optics Variable Filter System PC filter offers intriguing possibilities for planet-watchers. Be sure, however, that you have a shorty Barlow handy to bring things into sharp view. ■

**THE VFS-1.25** performs best during planetary viewing but can also be used when targeting deep-sky objects.



**THE DIAL** sets the filter to the color shade the observer desires. Future models will include a graduated scale on the wheel.

***Contributing editor Phil Harrington** is the author of five books on amateur astronomy, including* Star Ware.

PHOTOS: JAMES FORBES AND WILLIAM ZUBACK

## EQUIPMENT REVIEW

Software Bisque's rock-solid platform defines the high-end mount for serious observers and astroimagers. /// BY GREGORY TERRANCE

# The Paramount GT-1100 ME

For a telescope's full optical imaging power to be utilized, a mount capable of accurate tracking, efficient pointing, and solid design is required. For users hoping to access their telescopes remotely, the mount must also provide reliable software and a design that protects equipment from tangling and has definable slewing limits.

Slewing limits, in particular, are necessary since they prevent a go-to scope from colliding with structures or equipment that prevent it from having a full range of motion. When the user isn't present, telescope mount technology must protect the telescope on its own. All these safety and accessibility features come together in a red anodized covering in the latest Paramount telescope mount. The original Paramount GT-1100 set new standards for remote accessibility and introduced through-the-mount cabling.

The new GT-1100 ME continues this tradition of excellence. It began shipping in the spring of 2002 and introduced a new cable conduit that eliminates compatibility problems and allows for a larger number and range of telescope accessories. Additional improvements include a DC-servo control system, better stability, "Auto-Homing," and increased payload capacity. Conservatively rated for a payload of 125 pounds, the ME benefits from over a year's worth of effort and a complete redesign.

### The new ME

Unlike the original, the ME arrives basically assembled; once the declination shaft, saddle plate, and control panel are added, the mount is (mechanically) ready to go-to. The ME can be easily adapted to an existing pier when coupled with one of the Bisque adapter plates. The plates are available in heavy duty and lightweight versions at a cost of $99 or $135, respectively. Another mounting option is to use a Paramount welded pier, which makes attaching the interface to the mount a snap. The 10-inch (4.17 cm) diameter steel pier can be purchased for $495 in heights that range from 18 to 54 inches (7.5 to 22.5 cm).

The GT-1100 was the first commercially available mount with through-the-mount cable routing abilities. The original design supported a predetermined set of standard pass-through connections, but nonetheless eliminated or significantly reduced the number of cables drooping to the observatory floor. The ME takes this feature one step further by adding more standard connections and allowing the user to route additional cables through Bisque's "cable conduit."

The ME's cable conduit takes advantage of the large-diameter hollow shafts used for the declination and right ascension axes. Two side panels on the mount and a machined opening in the declination shaft provide access to the conduit, which is large enough to support all modern connectors. Running cables takes up to 40 minutes. The added flexibility of user-routed cables dramatically increases the usefulness of this feature and nearly ensures that technological advances won't soon make the mount obsolete. Built-in connections include camera power, focuser, auxiliary power (2), serial (2), parallel, and auto-guider control.

**EASY GRASP KNOBS** hold the telescope firmly in place. During setup, machined divisions on the mount are sufficient to get within one degree or better of polar alignment.

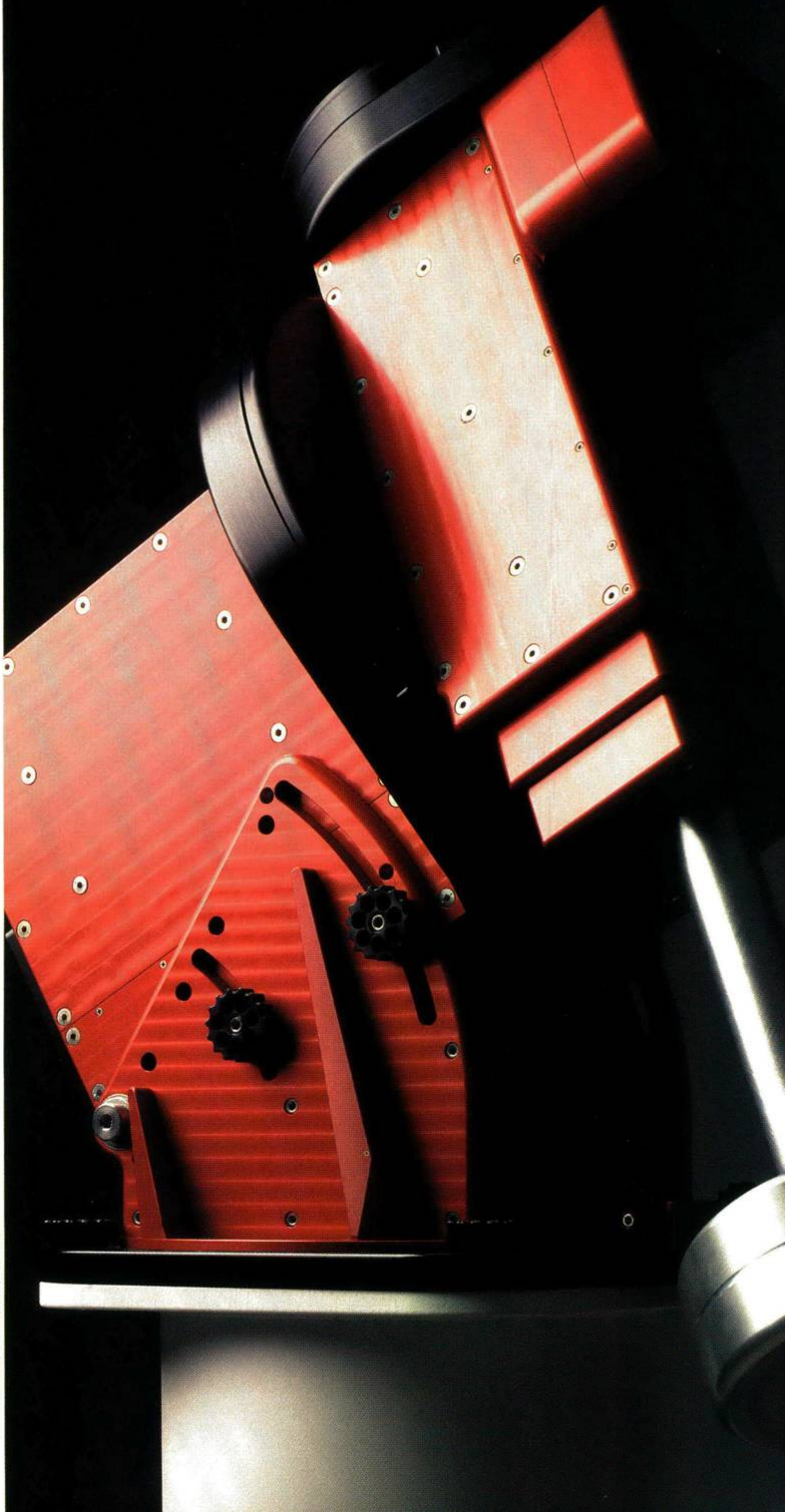
The ME has an altitude range from 15° to 58° with machined divisions on the mount that are sufficient to get within one degree or better during initial polar alignment. (A wedge is available if your latitude falls outside of this range.) Six retaining bolts hold the altitude adjustment in place. Four of the bolts are machined knobs that can be easily tightened by hand or wrench. The remaining two bolts serve as a pivot point and must be adjusted with an Allen wrench.

The altitude adjustments are made via a single, calibrated central column. A full turn of the altitude collar moves the mount one degree for central latitudes. For finer adjustments, each of the column tick marks is equal to approximately 2′ of movement. The azimuth adjustment is equally inventive. The entire 11-inch circular mount base serves, in essence, as an azimuth bearing. Adjustments are secured by two spring-loaded set screws that, according to Bisque, "allow adjustments to the mount's azimuth during polar alignment without disturbing the mount's altitude" (a fact confirmed during setup). The azimuth bearing can rotate the mount plus or minus 4°.

The ME's saddle plate, referred to as the Versa-Plate, can accommodate nearly any telescope mounting configuration imaginable. The 8 by 20-inch (3.3 by 8.3 cm) plate is machined so that it can be used in four configurations: centered, offset forward or backward (by approximately an inch), or rotated 90° for side-by-side operation with two telescopes. It has pre-drilled holes for telescope mounting rings as well as a central channel that accepts the popular Losmandy dovetail mounting plates. Four machined hand knobs allow the user to tighten down the dovetail plates securely.

The right ascension and declination worm drives feature a pivoting worm block on bearings that maintain contact with the gear and thus eliminate backlash. The right ascension drive gear features 576 teeth, is 11.45 inches in diameter, and utilizes a large 8.8-inch OD bearing. The declination has a 7.45-inch, 375-tooth gear with a 6.7-inch OD bearing. Both use a non-slipping, high-quality belt for safe and quiet movement. The right ascension periodic error is guaranteed to be below 5″. The worm-gear to drive-gear interface can be released for balancing or adjusted for the best performance.

All external components are stainless steel or anodized aluminum, and attention to detail is obvious; even the counterweight stop is machined and anodized. The 20-pound counterweights (two are included with the mount) can be used without tools and are visually elegant. Additional weights are $150 each. The declination shaft also comes with a standard 18-inch-long shaft that holds up to six counterweights, or an optional 6-inch-longer counterweight shaft can hold up to eight counterweights.



**POLAR ALIGNING IS SIMPLIFIED** with Paramount's non-coupled altitude-azimuth axes. Corrections to one axis can be made without requiring adjustments to the other.

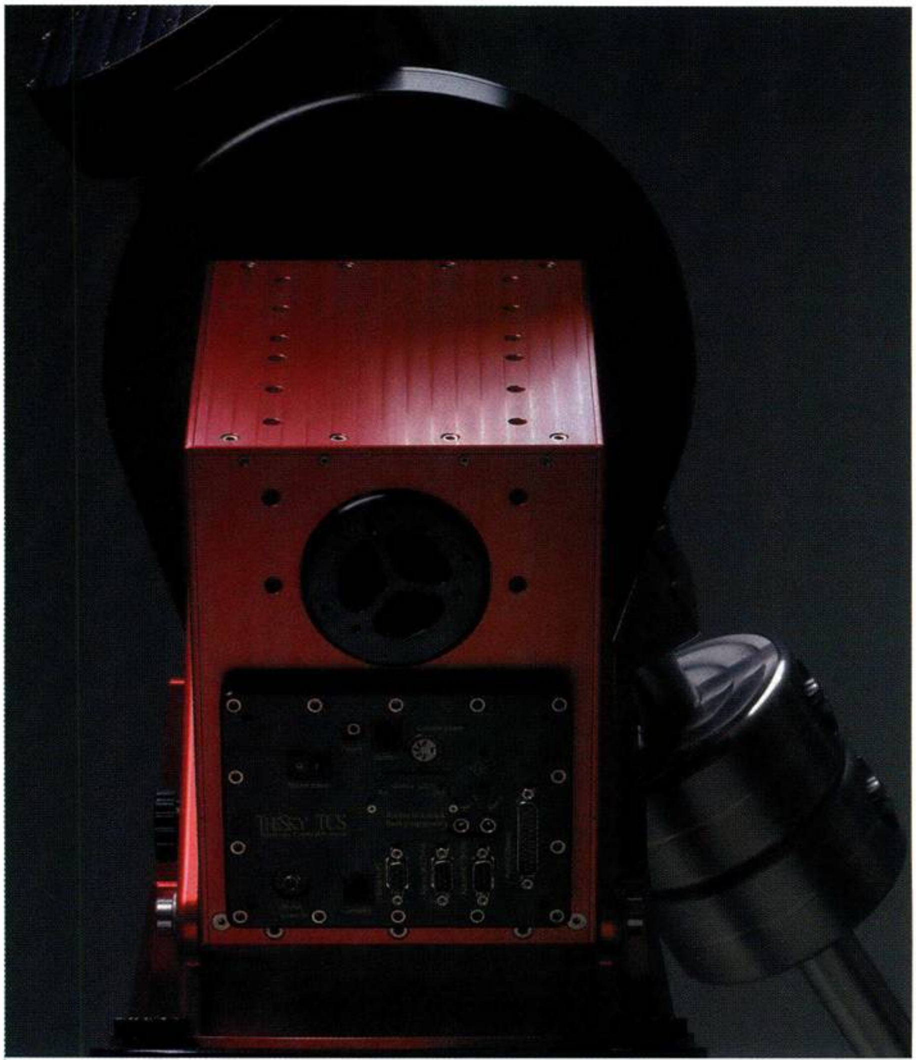
ALL PHOTOS COURTESY OF SOFTWARE BISQUE, INC.

## Telescope control

The Paramount's control system allows it to track virtually any object in the sky with the exception of an unannounced meteor or passing jet. Referred to as the MKS-3000 control system, it can track at true lunar and solar rates, minor planet or comet rates, as well as NEO and LEO satellite rates. Nearly any user-defined rate is possible when the mount is used in conjunction with TheSky. The brushless DC-servo motors that make these tracking and slew rates possible provide speeds approaching 5° per second in right ascension and 7° per second in declination.

Each axis of the mount has a built-in sensor that allows it to always know its orientation, even after power failure. The "AutoHome" feature can start the mount with an accuracy of better than 1″; that's important whether you are using a remotely operated observatory or just looking for a quick, accurate startup. The ME also has built-in "hard limits" that prevent it from tracking or slewing into itself. If you try to slew past the limits, the mount simply slows and stops. Additional "no-go" zones can be programmed, as can the slewing speed and acceleration/deceleration rates.

The Paramount ME arrives fully equipped with a wide range of software components that control mount functions, CCD and video cameras, and observatory domes, as well as scripted equipment control and telescope-pointing analysis. These programs are designed to work hand-in-hand with one another — most of the programs are extensive enough to warrant complete reviews. Due to space constraints, only the essential points are summarized here.



**THROUGH-THE-MOUNT CABLING** allows users to attach virtually unlimited accessories to their telescopes without fear of their cables getting tangled or drooping to the floor.

**TheSky:** TheSky is the primary telescope control package supplied with the ME. The latest version includes new features such as a graphically displayed periodic error chart, point-and-click satellite tracking, expanded star charts, and more. Software examples include the "Star Search," which systematically searches for a star outside the field of view, and a very accurate telescope motion control.

**TPoint:** TPoint works in conjunction with TheSky to provide polar alignment information and improve the mount's pointing performance. Individual stars are "mapped" (centered and logged) so that TPoint can create a model from the difference between where the telescope is pointing versus where it should be pointing. After enough stars are mapped, the software can compensate for telescope idiosyncrasies and polar alignment errors. For those so inclined, TPoint can also be used as a diagnostic tool for identifying mechanical ailments.

**CCDSoft:** CCDSoft is a sophisticated camera control, image acquisition, and image-processing program. An example of this software's advanced capabilities is AutoMapping, where CCDSoft is used with a digital video camera to automatically center and map a star for use with TPoint during mount modeling.

**Orchestrate, IAClient, and IAServer:** These three software programs allow telescope automation and/or control for remote observing. Orchestrate scripting software is used for remote/automated control of the telescope and a CCD camera. IAClient allows TheSky and CCDSoft to be controlled via the Internet. IAServer lets remote clients access the telescope and CCD systems.

## Performance

I tested the ME with a variety of telescopes that included a combination of the following equipment: a 14-inch f/10 RCOS Ritchey-Chrétien, a Takahashi FSQ-106, and a Takahashi FC60E. Total payloads ranged from 25 to 90 pounds.

The Versa-Plate's dovetail mounting system made it easy to switch between equipment configurations. The saddle plate's mounting holes (more than 100 of them!) were intended for mounting rings but also proved useful for tie-wrapping

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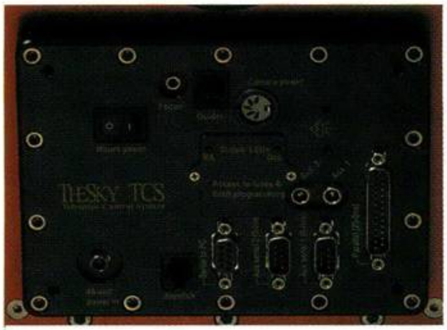
**Gregory Terrance** *enjoys CCD imaging from his backyard observatory in Lima, New York. His Paramount regularly keeps him tangle free.*



**STANDARD CONNECTIONS** allow users to plug many devices straight into the telescope. The Paramount GT-1100 ME is designed to be driven with Bisque's "TheSky" software.

loose wires and as a handy reference for making balance adjustments. Regardless of what telescope ultimately ends up on the ME, I can't imagine the Versa-Plate having to be modified to accept it.

Although I never ran the mount remotely, I found the ME's cable conduit to be a significant addition to an already great mount. I was able to use a variety of imaging equipment without a single cable drooping to the floor (including a CCD camera, video camera for mapping, color filter wheel, digital focuser, and dew heaters). The extra capacity of the conduit allows nearly anything to be routed through the mount. A significant side benefit of the pass-through was the sense of relief knowing that nothing was going to get snagged as the mount slewed.

There are limitations to what the cable conduit can handle, however. Wires with large connectors cannot fit through the pass-through openings, and the number of cables is limited by space. Even so, I doubt that there are many situations where it would be found wanting. The process of passing a cable through the mount took about 20 minutes; most of that time was spent removing and replacing the declination side panel.

## Polar alignment

Any decent telescope mount has provisions for making altitude and azimuth adjustments. Unfortunately, these adjustments almost always affect one another — even on the best mounts. To this end, I've never experienced a mount closer to having a true separation between the altitude and azimuth adjustments than the ME. The Paramount's adjustments are also calibrated, which makes polar aligning a more predictable process.

To set the mount's polar alignment, I used an inexpensive surveillance video camera to perform a short mapping run. The mapping process fed data to TPoint to assess the polar alignment accuracy. With at least six stars mapped (constellations work well), TPoint had enough information to determine the mount's offset from the celestial pole, and the software could recommend adjustments.

TPoint displays the mount's offset values in arcminutes and arcseconds. It also assigns a "σ" error value to its recommendations — low s indicates a high confidence level in the data. Once adjustments are made, another mapping iteration is required to determine the polar alignment improvements. Using these procedures, I was able to get within 20″ of true north in both altitude and azimuth without any heroic efforts.

## The nitty gritty

The Paramount's movements were always well damped and controlled — assets evident as the mount quickly moved from star to star during video mapping. As the star's image zipped into view, it stopped nearly instantaneously, even when eyepiece projection was used. These are important virtues, but a mount's tracking, pointing, and guiding abilities are also prime factors in its potential as an imaging platform. Here is a synopsis of my tests on the ME:

Tracking: The ME tracked superbly. I was able to consistently take 10-minute unguided exposures at medium focal lengths with nice round star images resulting. Although its operation was not thoroughly explained, activating the ProTrack features further improved the ME's tracking capabilities.

Pointing: The ME is specified to have less than an arc minute RMS all-sky pointing. My pointing tests were much better — typically in the 10″ to 30″ range (after a sufficiently large TPoint model was established).

Guiding: The ME successfully calibrated with an autoguider on its very first attempt. The lack of backlash in both drives made this a common occurrence and a guider image frequency of 10 or 20 seconds always produced round star images during long integrations.

Periodic error: The periodic error values were affected by the mount's balance, telescope weight and even the night it was measured. The pre-PEC periodic error measurements ranged from 5″ to an astonishingly low 2″. With the mount properly set up, typical values were at 3″.

PEC: The PEC setup was fascinating to watch as it graphed the mount's periodic error. Periodic error values dropped to below 2″ after applying PEC. Although the mount's autoguiding was always regular and smooth, it noticeably improved when PEC was turned on.

It should be noted that much of the mount's success depended on the software setup: Incorrect sequences of steps, careless mappings, or "check boxes" left unchecked resulted in less than optimum performance with the ME. Correctly implemented, however, the hardware and software performed with stellar results; certainly the details and subtleties of the software will keep the Paramount's "User Group" busy for years to come.

The GT-1100 ME combines a sophisticated design, superb machining, and advanced software to place it at the vanguard of today's telescope mounts. Priced at an even $10K, it is highly recommended for enthusiastic imagers who want to make the most of every clear night. Tipping the scales at only 65 pounds, its red anodized exterior belies its heavyweight capabilities and an awesome weight-to-payload ratio. Fortunately, its outward appearance and the manufacturer's specifications were backed up with superb performance; the critical areas of tracking, pointing, and guiding were excellent in every respect.

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Giant binoculars provide bright, detailed views of the cosmos for beginners and veterans alike. /// BY PHIL HARRINGTON

# Two eyes on the sky

Many of us took our first tentative steps into the universe while clinging to a sturdy pair of binoculars. Their wide-eyed view of the cosmos revealed new wonders that couldn't be appreciated — or even seen — by our eyes alone. As we grew bolder in our explorations, binoculars could take us starhopping to our first deep-sky objects and bring into focus a visual definition of comets and planetary rings.

But binoculars aren't just for beginners. An increasing number of seasoned amateur astronomers are adding giant binoculars to their equipment arsenal. For them, the magic of binoculars is not only still there, it is better than ever.

Giant binoculars dwarf normal binoculars, magnifying images 10 times (10x) or more and measuring upward of 60mm in aperture. In recent years, the giant-binocular marketplace has grown at an impressive pace, with dozens of models becoming available for amateur astronomers. Some are comparable in price to the more common 7x glasses, while others cost hundreds or even thousands of dollars more. To help observers find the binoculars that will best fit their needs, I have pulled together a large sample of giant binoculars and put them through a series of head-to-head tests.

Each pair of binoculars is built around a set of internal Porro prisms. Devised by Ernst Abbe in 1894, Porro-prism binoculars gather light through a pair of objective lenses, bounce it through two sets of prisms, and into the eyepieces. This set of reflections and magnifications results in a rectified — right side up — magnified view.

Different materials are able to transmit light, via reflection or refraction, with varying efficiency. The higher the optical efficiency of an instrument, the brighter a viewed object will appear. High quality Porro-prism binoculars feature prisms made from BaK-4 (barium crown) glass, while less expensive models use prisms of BK-7 (borosilicate) glass. Prisms made of BaK-4 glass transmit to the eyepiece practically all the entering light (what optical experts call "total internal reflection") and create bright, sharp images. Prisms made of BK-7 glass are not as efficient; consequently, objects appear dimmer. All of the binoculars in our test group have Porro prisms made from BaK-4 glass.

In an ideal pair of binoculars, all the light that hits the aperture will pass through the binoculars to a viewer's eye. This means that if you looked at the front of a pair of binoculars while someone is viewing the Moon, you would not see the Moon's reflection in the lenses. In real life, lenses do reflect some of the light that hits them. To improve light transmission and reduce scattering, most lenses are coated with thin layers of magnesium fluoride. An uncoated lens reflects about 4% of the incoming light, while lenses coated with magnesium fluoride scatter away 1.5%. You can identify a coated lens by looking for a purplish tint when the binoculars are held at a narrow angle toward a light. For the best results and the brightest images, "fully coated optics" are preferred. Unless "fully" is explicitly stated, chances are that some internal lenses are not coated.

While a single coating on each optical surface is good, building up several thin layers of coating is even better for enhancing performance. So-called "multicoated" lenses reduce reflection to less than 0.5% and will show a greenish reflection when turned toward a white light. Binoculars that have "fully multicoated" optics are the best of the best for astronomical viewing.

## Binocular specifics

Before jumping into head-to-head comparisons, I will summarize some of the basic characteristics of each of the binoculars I reviewed. In all cases the binoculars' magnification (e.g. 15x) and aperture size (e.g. 70mm) are given as "magnification x aperture" (e.g. 15x70). Please see the side chart for details on prices and manufacturer information.

**Burgess Optical 15x70.** The 15x70s sold by Burgess are noteworthy not just for their fully multicoated optics, but also for their low price — only $100. That's less than a quarter of what you would spend for similar binoculars from better-known manufacturers, such as Fujinon and Nikon (reviewed below). The Burgess barrels are covered with a smooth, flat-black vinyl that is easy to hold. Their knurled center-focusing knob works smoothly and evenly, while collapsing eye guards extend around the eyepieces to shield the observer from stray light. The Burgess 15x70s have center-focusing eyepieces, a soft carrying case, as well as a standard tripod socket built into their center hinge assembly. The tripod socket allows attachment to a tripod or other support via a commonly available 90-degree tripod adapter (sold separately). Burgess 15x70s are light enough that hand support is possible for short periods.

**BURGESS OPTICAL 15X70s** are lightweight and affordable. For just around $100 you get fine optics coupled with solid engineering and all the standard features. With a built-in tripod socket, no specialized parts should ever be needed.

**FUJINON 16X70 FMT-Xs** weigh in at 76 ounces and require a tripod for anything more than a quick look. Fujinons come with a hard case and a padded shoulder strap to make transport safe and comfortable.

**ORION 20X80 MEGAVIEW BINOCULARS** incorporate rubberized dew caps into each barrel to keep the optics dry on high-humidity nights. The dew shields also help block out any stray light.

**OBERWERK 15X70 GIANTS** held their own in optical testing and presented views that were sharp and contrasty. Minimal pincushion distortion is more than made up for in the Oberwerk's exceptional price ($150).

**ORION 15X70 LITTLE GIANT II BINOCULARS** come with a 90-degree tripod adapter and a hard case. Part of a large line of Little Giant II binoculars, the 15x70s are well made and offer smooth focusing and a quality feel.

**NIKON 18X70 IF SP ASTROLUXE BINOCULARS** have individually focusing eyepieces and a wide apparent field of view. These binoculars do not have a standard tripod socket and require a special bracket for mounting.

**Fujinon 16x70 FMT-X.** Fujinon 16x70 FMT-SX binoculars, along with the 6x30, 7x50, and 10x70 versions, are members of Fujinon's Polaris binocular series. All units feature leatherette-covered sealed barrels filled with dry nitrogen to lessen the chance of the internal lens fogging in high-humidity environments. In order to maintain their airtight seal, Fujinon eyepieces focus individually. Focusing is smooth, but difficult to do when supporting the binoculars by hand.

In general, Fujinon binoculars require a tripod. They weigh 76 ounces, which is heavier than any other binoculars in this size class. While this certainly gives the binoculars a feeling of durability, it also makes hand-support impractical.

The Fujinon binoculars' optics are fully multicoated, and the 16x70s feature a standard tripod socket as well as a hard case, which offers excellent protection for the binoculars when not in use.

**Nikon 18x70 IF SP Astroluxe.** Like Fujinon's binoculars, Nikon's 18x70 Astroluxe binoculars feature fully multicoated optics set in sealed barrels filled with dry nitrogen. Again, the individually focused eyepieces, required to maintain the watertight seal, turn smoothly without binding or shifting.

Since the Nikon binoculars weigh 68 ounces, mounting them on a tripod is necessary. Unlike most of the other binoculars I reviewed, the Astroluxe binoculars do not include a standard tripod socket. Instead, Nikon sells a special tripod adapter that clamps onto the post between the binocular barrels. Although this works well, it costs much more than the L-shaped brackets used by most binoculars. Additionally, since most camera tripods are not tall enough for viewing the sky comfortably, many amateurs favor parallelogram binocular mounts. Unfortunately, the design of the Nikon tripod adapter makes it impossible to attach the binoculars to many of these mounts without a second adapter plate. If you are planning to attach these Nikons to parallelogram binocular mounts, contact the mount's manufacturer beforehand for recommendations. The Nikons also include leatherette-covered barrels and come with a hard case for safe storage.

**Oberwerk 15x70 Giants.** Virtually identical to the Burgess 15x70s mentioned above, the Oberwerk 15x70 Giants are also light enough to be supported by hand for brief periods. A tripod or other support, however, is strongly recommended for extended observing. The Oberwerk binoculars are covered with a smooth, black vinyl and have center-focusing eyepieces, a built-in tripod socket, and a soft carrying case. The knurled center-focusing knob turns smoothly and precisely, with no detectable binding or image shift.

**Orion 15x70 Little Giant II.** Few companies offer such a wide selection of astronomical binoculars as Orion Telescopes and Binoculars. Their line-up of 70mm Little Giant II binoculars includes 11x and 20x models, as well as the 15x version included here. The Orion Little Giant II binoculars feature a leatherette covering, fully multicoated optics, and a built-in tripod socket. Construction quality is excellent, focusing is very smooth, and their hard case offers superb protection against those inevitable bumps and bounces. Orion also thoughtfully includes a 90-degree tripod adapter with each pair.

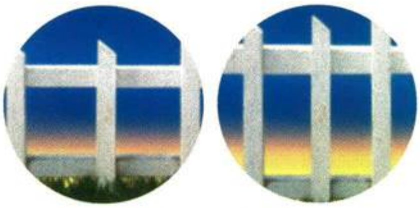
**Orion 20x80 MegaView binoculars.** Optically and mechanically, Orion's top-end MegaView binoculars have all the right stuff, including fully multicoated optics. The center-focusing knob moves smoothly, with just the right amount of resistance to ensure a positive focus. Each of the barrels is covered with a dark gray leatherette material. A very nicely made latching hard case is also included.

Proving that they were designed with astronomical viewing in mind, MegaView binoculars incorporate into each barrel a built-in rubberized dew cap that can be pulled out in front of each objective lens when needed. This is an especially welcome feature in damp environments as well as anywhere that extraneous light can spoil the view.

A central rod bridging the length of the binoculars, extending between the prism housing and the objectives, supports the long barrels, preventing them from sagging under their own weight. A clamping tripod adapter slides along this rod, permitting direct attachment to a photographic tripod without the need for a separate adapter. Unfortunately, this same feature also means that a special adapter is needed to attach the MegaViews to some popular parallelo-

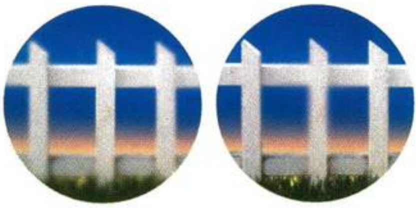
**PARKS ZCF DELUXE BINOCULARS** are well constructed and feature an extra hinged bridge support between the barrels of the larger sets. This gives the heavy 80mm lenses an extra measure of support. The Parks binoculars come with a 90-degree tripod adapter.

**ASTIGMATISM** elongates images on either side of focus. To the inward of focus, images will stretch horizontally, while to the outward of focus, the elongation will flip 90°, extending them vertically.



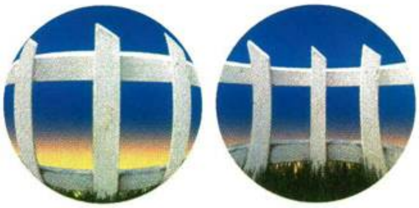
Inward of focus     Outward of focus

**FIELD OF CURVATURE** occurs when light rays passing through the lens edge do not focus in the same plane as those passing through its center. The periphery of the field is blurred when the center is focused, and vice versa.



Periphery out of focus     Center out of focus

**DISTORTION** contorts objects geometrically, changing straight lines into arcs. With positive, or pincushion, distortion, lines bend outward (convex), while with negative distortion, they bend inward (concave).



Positive     Negative

gram binocular supports. As mentioned earlier, contact the mount's manufacturer for recommendations.

**Parks Optical 10x70 ZCF Deluxe.** Parks Optical offers four giant binoculars in the 70 to 80mm range. The Parks 10x70 ZCF Deluxe model features fully multicoated optics, a black leatherette-coated body, objective and eyepiece caps, a conventional tripod socket, and comes with a 90-degree tripod adapter. The center-focusing eyepieces move smoothly when the focusing wheel is turned, and no backlash or play is evident. The included hard case provides a sturdy home for the binoculars when they are not in use, protecting them from damage as well as dust and dirt.

**Parks Optical 11x80 ZCF Deluxe.** Parks 11x80 ZCF Deluxe binoculars include all of the features found in their 10x70 binoculars (reviewed above) and add a hinged bridge support between the barrels near the objective lenses. Although the central hinge should be strong enough to maintain the binoculars' optical alignment, a hinged bridge offers an extra measure of safety for these heavy 80mm barrels. Again, construction quality is excellent, with precise focusing and a balanced feel.

**Swift Instruments 20x80 Satellite.** Swift has been in the binocular business for more than 75 years, making them one of the oldest names in the industry. In the giant-binocular arena, Swift offers three designs: 15x60, 11x80, and the 20x80s included here. Swift 20x80 Satellite binoculars include multicoated optics, a standard tripod socket built into the center hinge, and a smooth center-focusing thumbwheel. The Swift Satellites also come with a rugged, latching hard case.

**SWIFT 20X80 SATELLITE BINOCULARS** are solid performers in all arenas. At $1,950, their excellence is as expected.

**ZEISS 15X60 B/GA T* CLASSIC** are physically small, optically near perfect and provide excellent light transmission.

**Zeiss 15x60 B/GA T* ClassiC.** Although the smallest of the bunch gathered here, the Zeiss 15x60 ClassiCs are giant binoculars in every sense of the word. Coated with rubber armor to protect them from bumps and bangs, these binoculars feature fully multicoated optics that boast an impressive available-light transmission rate of 95%. The center-focusing eyepieces turn very smoothly; in fact, the focuser was judged to be the smoothest of all. Unlike the other center-focusing models here, the focus wheel is located toward the front of the binoculars, which users with smaller hands may find difficult to reach when grasping the binoculars. The focuser's location also made it impossible for Zeiss to design a tripod socket into the center hinge. Instead, like the Nikons, Zeiss sells a custom adapter that clamps onto the binoculars' central support bar.

The Zeiss ClassiC binoculars also include rubber objective lens covers that stay attached to the barrels when in use. Although this prevents them from getting lost in the dark, they tend to flop back and forth while viewing through the binoculars. I ended up folding them in between the barrels, which seemed to resolve the problem. The sample pair used for this test did not come with a carrying case.

## Daytime optical testing

To most efficiently evaluate each pair of binoculars, they were tested during the day as well as at night. Daytime observations are best for checking field curvature, astigmatism, and distortion, while stellar observations provide a fair measure of each pair's image brightness and contrast, as well as potential spherical and chromatic aberration. Daylight is also best for checking the clarity and consistency of optical coatings and looking for any contaminants left in the barrels during manufacturing. All of the models I reviewed were free of internal dust, metal shavings, and other impurities. Further, each objective lens and eyepiece had evenly applied coatings that were free of imperfections, such as unevenness or other blemishes. While nothing less should be expected from the high-end brands, it was reassuring to see that quality control is being attended to even in econo-binoculars.

Daytime tests were conducted using a distant picket fence whose horizontal and vertical posts would serve as good references for checking distortion and field curvature. The 16x70 Fujinon FMT-SX binoculars were the only pair in the group to show zero distortion. The fence stayed straight and true whether viewed at the center of the field or toward an edge. The Nikon binoculars displayed some very minor negative distortion, while I saw minimal positive distortion in the Zeiss ClassiCs. The Orion MegaViews showed slightly more negative distortion than the Nikons, while the 11x80 Parks Deluxe binoculars showed only slightly more positive distortion than the Zeiss glasses. Finally, pincushion distortion was perceptible over the outer quarter of the field in the 10x70 Parks and the outer third of the field in the Burgess Optical, Orion Little Giant II, and Oberwerk 15x70s, as well as the Swift 20x80s.

Field curvature was nonexistent in the Fujinon, Nikon, Zeiss, Parks 11x80, and Orion MegaView glasses and was only minimally invasive in the others. I also found that, happily, none of the binoculars tested showed any appreciable astigmatism, which is usually associated with poorly made or poorly collimated optics, or improper manufacturing.

## Nighttime performance

Daytime tests are fine, but judging binoculars' true astronomical worth can be done only under the night sky. While smaller binoculars are great for scanning the sky and taking in the big picture, these larger, higher-powered binoculars are ideal for picking out specific deep-sky targets nestled among the stars. As a result, to get the most out of each, they really need to be mounted on a secure support, which is how I used and tested each.

The Zeiss 15x60 ClassiCs surpassed the other binoculars reviewed when it came to viewing the heavens. Image sharpness and especially contrast were remarkable, proving that Zeiss' "T" coatings are arguably the finest in the industry. After viewing the summer Milky Way through these binoculars, I felt that I had just seen the sky as I never had before. I can't remember another pair of binoculars that brought out as much detail in the many patches of dark nebulosity that speckle the Milky Way through Sagittarius and Scutum as the Zeiss binoculars did. This, coupled with the eyepieces' wide apparent fields of view, made for some very enjoyable viewing.

The Fujinon 16x70 FMT-SXs are renowned as one of the finest pairs of modern astronomical binoculars, and with good reason. Their total lack of distortion and field curvature translates into sharp, flat, star-strewn fields. Again, image contrast and resolution are outstanding, as is image brightness and apparent field of view. The only optical flaw I could detect visually was a very minor amount of spherical aberration around brighter objects.

| MODEL AND MANUFACTURER | EXIT PUPIL | EYE RELIEF | FOV | WEIGHT | TYPICAL COST | CONTACT INFORMATION |
|---|---|---|---|---|---|---|
| Burgess Optical 15x70<br>Burgess Optical Company | 4.6mm | 16mm | 4.4° | 46oz | $100 | 3613 Dyestone Gap Rd., Knoxville, TN 37931<br>[t] 865.769.8777<br>http://www.burgessoptical.com |
| 16x70 FMT-SX<br>Fujinon | 4.4mm | 12mm | 4.0° | 76oz | $600 | 10 High Point Drive, Wayne, NJ 07470<br>[t] 973.633.5600<br>http://www.fujinonbinocular.com |
| 18x70 IF SP Astroluxe<br>Nikon | 3.9mm | 15mm | 4.0° | 68oz | $1,200 | 1300 Walt Whitman Road, Melville, NY 11747<br>[t] 800.645.6687 or 631.547.4200<br>http://www.nikonusa.com |
| Oberwerk 15x70 Giant<br>Oberwerk Corporation | 4.6mm | 16mm | 4.3° | 53oz | $150 | 2440 Wildwood, Xenia, OH 45385<br>[t] 866.244.2460 or 937.372.5409<br>http://www.bigbinoculars.com |
| 15x70 Little Giant II<br>20x80 Mega View<br>Orion Telescopes and Binoculars | 4.7mm<br>4.0mm | 8mm<br>16mm | 4.0°<br>3.5° | 47oz<br>84oz | $280<br>$490 | P.O. Box 1815, Santa Cruz, CA 95061<br>[t] 800.676.1343 or 831.763.7000<br>http://www.telescope.com |
| 10x70 Deluxe ZCF<br>11x80 Deluxe ZCF<br>Parks Optical | 7.0mm<br>7.3mm | 17mm<br>20mm | 5.0°<br>4.5° | 62oz<br>82oz | $300<br>$400 | P.O. Box 716, Simi Valley, CA 93062<br>[t] 805.522.6722<br>http://www.parksoptical.com |
| 20x80 Satellite<br>Swift Instruments, Inc. | 4.0mm | 16mm | 3.5° | 78oz | $1,950 | 952 Dorchester Avenue, Boston, MA 02125<br>[t] 800.446.1116 or 617.436.2960<br>http://www.swift-optics.com |
| 15x60 B/GA T* Classic<br>Carl Zeiss Optics | 4.0mm | 15mm | 4.3° | 56oz | $1,950 | 1 Zeiss Drive, Thornwood, NY 10594<br>[t] 800.338.2984<br>http:// www.zeiss.com |

| MODEL | RESOLUTION | BRIGHTNESS | CONTRAST | SHARPNESS | VIEWING COMFORT |
|---|---|---|---|---|---|
| Burgess Optical 15x70 | ☾☾☾ | ☾☾☾ | ☾☾☾ | ☾☾☾ | ☾☾☾☾ |
| Fujinon 16x70 FMT-SX | ☾☾☾☾ | ☾☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾☾ | ☾☾☾☾☾ |
| Nikon 18x70 IF SP Astroluxe | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾☾ |
| Oberwerk 15x70 Giant | ☾☾☾ | ☾☾☾ | ☾☾☾ | ☾☾☾ | ☾☾☾☾ |
| Orion 15x70 Little Giant II | ☾☾☾ | ☾☾☾ | ☾☾☾☾ | ☾☾☾ | ☾☾☾ |
| Orion 20x80 Mega View | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾ |
| Parks 10x70 Deluxe ZCF | ☾☾☾☾ | ☾☾☾ | ☾☾☾ | ☾☾☾☾ | ☾☾☾ |
| Parks 11x80 Deluxe ZCF | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾ | ☾☾☾☾ | ☾☾☾ |
| Swift 20x80 Satellite | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾ |
| Zeiss 15x60 B/GA T* ClassiC | ☾☾☾☾☾ | ☾☾☾☾☾ | ☾☾☾☾☾ | ☾☾☾☾ | ☾☾☾☾☾ |

☾☾☾☾☾ exceptional; ☾☾☾☾ very good; ☾☾☾ good; ☾☾ fair; ☾ poor

## Overall evaluation

The Nikon 18x70 Astroluxe binoculars are also exceptional astronomical instruments. Images are tack sharp across all but the outer 5% or 10% of the field, and contrast is also very high. Comparing them side-by-side to the Fujinons, however, I felt they were slightly inferior in terms of image sharpness and contrast. Still, the eyepieces' wide apparent fields of view and excellent focus certainly carried them high in the overall ratings.

I was also very impressed with Orion's 20x80 MegaViews. Image sharpness and contrast were very good, as was eye relief, which made viewing very comfortable. A slight amount of chromatic aberration was evident around brighter objects but was certainly not objectionable. On the plus side, their slightly larger light-gathering area helped brighten objects that were comparatively dim through the Fujinon, Nikon, and Zeiss binoculars.

The Swift 20x80 Satellite binoculars are also solid performers. Their deeply recessed objective lenses helped keep image contrast high, even when viewing near a porch light, a common obstacle for city dwellers. Resolution and image brightness were both very good, as were their apparent field of view and comfortable eye relief.

Both of the Parks binoculars also showed sharp images and good contrast. While their apparent fields of view were the narrowest of the group, eye relief was excellent, making for comfortable viewing even if the observer must wear eyeglasses. As would be expected, the 80mm glasses produced the brighter images of the two, giving an especially nice view of the Double Cluster in Perseus as it rose over distant trees. (As a side note, I also tested 15x80 and 20x80 Parks Deluxe binoculars, but found that both show greater distortion and field curvature than the 11x80s.)

Finally, of the three 15x70 binoculars included here, the Orion Little Giant IIs were the best in terms of image brightness, contrast, and especially sharpness. Eye relief was a little short, however, which is an important consideration for eyeglass wearers. The Oberwerk and Burgess 15x70 binoculars, which appear to be twin instruments in nearly every respect, held their own against all of the binoculars here, producing images that were both sharp and contrasty. No, they were not as sharp as, say, the Zeiss or Fujinon binoculars, but given their amazingly low prices, these two binoculars are breaking new ground in the giant-binocular market.

Binocular astronomy has certainly come of age, thanks in large part to giant binoculars like those reviewed here. Since prices span such a broad range, just about any amateur can now enjoy the thrill of viewing the night sky through giant binoculars without having to break the bank. Watch these pages next month for a review of three sets of binoculars with apertures as large as 100mm. ◼

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**Phil Harrington** *has spent more than three decades viewing the sky with binoculars. His book* Touring the Universe Through Binoculars *is available at bookstores as well as through his web site, www.philharrington.net.*

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| | |
|---|---|
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| **TV-85,** optical tube only | $1680^{00}$ |
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Vixen

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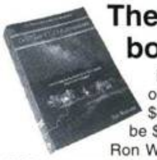
4" f/9 ED apochromatic refractor
(shown with optional motor drive)



## The best CCD book. Period.

Before you spend $3000 on a CCD camera, spend $49.95 on this book. It will be $49.95 well spent.

Ron Wodaski's book **The New CCD Astronomy** is simply the best and most complete reference available about CCD imaging for the beginning to advanced CCD astrophotographer. It includes everything you need to become proficient at CCD imaging, including a free subscription to on-line updates and reference materials. This is the only CCD reference book you'll ever need to buy. *Period.*

## Over 1,000,000 people a year visit our website for reliable info, helpful features, and secure on-line shopping.

## www.astronomics.com

## Our four brands of light pollution filters bring dark skies to your light-polluted world.

If city lights are blocking your view of the heavens, you can get rid of that light pollution with one of the many light pollution filters we stock. They often make the difference between seeing nebulas and galaxies from cities and suburbs and missing them completely.

We carry **Celestron** broadband light pollution filters in both 1.25" eyepiece and Schmidt-Cassegrain rear cell versions.

We carry **Meade** broadband, narrowband, and Oxygen III filters in both 1.25" eyepiece versions and rear cell versions for Schmidt-Cassegrain use.

We carry **Sirius** 1.25" and 2" broadband light pollution filters – nebula, Oxygen III, H-Beta, planetary contrast enhancement filters, and Neodymium planetary contrast filters for eyepiece use; their variable filter system; and their IR and UV photo filters.

We carry the **Thousand Oaks** broadband, narrowband, Oxygen III, and H-Beta filters in both 1.25" and 2" versions for eyepiece use.

## We stock Pentax XL eyepieces from $227^{50}$.

From 5.2mm to 40mm, we stock all of the Pentax wide field (55° to 65°) XL eyepieces. Each has a rotate-to-adjust-the-eye-relief eyecup, ED glass for exceptional edge to edge sharpness, and a long 20mm eye relief that's perfect for those who wear eyeglasses.

| | |
|---|---|
| 5mm 1.25" | $\$244^{50}$ |
| 7mm 1.25" | $237^{50}$ |
| 10.5, 14, 21, or 28mm 1.25" | $227^{50}$ |
| 40mm 2" | $244^{50}$ |
| 8-24mm zoom 1.25" | $379^{00}$ |

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# We'll sell you the *right* telescope.

## Why wait? We'll ship your Meade LX90 from stock.

Meade 8" LX90

Meade prices are about the same anywhere you call. So why order a Meade scope or accessory from a dealer who charges your credit card, then makes you wait and wait until he finally gets around to ordering what you want? Not when you can usually get the Meade scope you want from stock . . . right now . . . at the right price . . . right here at ***astronomics.***

The **Meade LX90** will let you enjoy 8" go-to astronomy for not a lot of money. An LX90 with standard optical coatings is only \$1695. UHTC (Ultra High Transmission Coatings) optics that have up to 20% brighter images are only \$1870. Both versions come with a heavy-duty adjustable height tripod, an Autostar go-to computer with a built-in 30,223 star and object data base, a big and bright 8 x 50mm finder, and a 26mm Super Plössl eyepiece.

We usually have the LX90 in inventory at all times (both the standard and UHTC optics versions), so the chances are good you can get *your* LX90 with little or no delay. If Meade is shipping the LX90 *(or any Meade telescope)* for a dealer to keep in stock, the chances are very good that we *have* it in stock.

## 7" to 10" Meade GPS UHTC scopes ship from stock. They do all the work so you can see 20% more.

Meade 8" LX200 GPS with UHTC

**\$2670**

Meade LX200GPS telescopes have all the features you've dreamed about since you started astronomy – plus optional UHTC (Ultra High Transmission Coatings) optics that give you up to 20% higher light transmission so you can see 20% more of the Universe.

Meade's *fully automatic* GPS (Global Positioning Satellite) alignment system, with its true north and true level sensors and automatic magnetic declination correction, takes the time and guesswork out of setting up your scope. You'll be observing in mere minutes. The built-in computer, with a database of over 145,000 stars and objects, finds deep space and solar system objects for you *automatically*. You'll spend more of your time looking *at* heavenly bodies and less time looking *for* them.

We keep the 7", 8" and 10" Meade LX200GPS scopes in stock. Chances are good we have one in stock for you.

## The NexStar 11 got a rave review. You can have yours next week!

Celestron's 11" go-to GPS scope – the **NexStar 11 GPS** – got a *rave* review in *Sky & Telescope*. The review gave it "an enthusiastic two thumbs up and a gold star." They said it has "brains and good looks. The NexStar 11 GPS puts Celestron's time-tested 11-inch f/10 Schmidt-Cassegrain optics in a sleek new package that includes some of the most advanced electronics ever offered in a mass-produced telescope . . . Celestron is the first to take Go To scopes to the next step in their evolution, and it's a nice step indeed."

Starbright multicoated Fastar-compatible optics are *standard* with a NexStar. Fastar optics are unavailable with other scopes. We have the NexStar 11 GPS in stock. Call us and you'll be observing with yours in about a week. **\$2999**

NexStar 11 GPS

## Multicoated optics? Standard on the NexStar 8 GPS.

NexStar 8 GPS

**\$2499**

The Celestron **NexStar 8 GPS** Schmidt-Cassegrain has all the bells and whistles you expect from an 8" GPS scope, including *standard equipment* Starbright high transmission multicoated optics for brighter images – plus it has many unique features unavailable in other scopes!

For example, you can convert its unique Fastar f/10 optical system to a blazingly fast f/1.9 focal ratio for wide field CCD imaging. With an optional Fastar lens and a \$1295 SBIG ST-237A CCD camera, you'll record a huge 32 x 42 arc minute field. That's larger than the full Moon and more than three times the sky area imaged by a \$7695 camera on other 8" telescopes without Fastar optics!

Of all the computerized GPS scopes, *only the Celestron NexStars have multicoated Fastar optics!*

## The *new* Celestron CGE series scopes. Designed to meet a mounting demand.

**\$4149**

Celestron CGE1100

Astrophotography with a fork-mounted go-to Schmidt-Cassegrain does have its drawbacks. You can't take long exposure photos with an altazimuth mount scope without adding a costly equatorial wedge or field derotator. If you use a wedge, you can't image near the celestial pole or the southern horizon, and tube vibrations become a problem. Use a field derotator and you both lose periodic error correction and can't image at the zenith. In larger apertures, fork-mounted scopes require two people to transport and set up.

Celestron's CGE go-to computerized German equatorial mount scopes solve all these problems. Even the largest 14" CGE1400 can be set up by one person. A German mount can access all parts of the sky, without adding a wedge or field derotator. And a German equatorial mount is noted for its lack of vibrations.

Multicoated optics, available as complete go-to systems in apertures from 8" to 14" and as a go-to mount only, optional GPS available for only \$199. See our website for full details.

## A 5" GPS-ready scope for only \$899!

NexStar 5i

**\$899**

shown with optional photography accessories, tripod, and computer

The **Celestron NexStar 5i** is the first 5" telescope to have a fully automatic GPS go-to computer available as an option. No other 5" telescope has a GPS system! Even better, the modular nature of the NexStar 5i means that you can build up to a fully automatic GPS system gradually, starting at only \$899 for a complete working tabletop scope and adding computer, GPS, etc., as wanted. And multicoated optics are *standard equipment* with the NexStar 5i, not an extra-cost option. NASA uses 5" Celestron multicoated optics on the Space Shuttle. Don't your eyes deserve the same premium images?

## Eyepiece storage cases from \$2$^{49}$.

Bolt-type containers protect eyepieces dew and dust. Foam inserts cradle eyepieces to protect them from accidents. Our website at **www.astronomics.com** lists which eyepieces fit into which containers (including other containers not listed below).

| | | |
|---|---|---|
| **42mm x 60mm** | holds most Celestron NexStar, Meade Series 3000, and TeleVue Plössls. | **\$2$^{49}$** |
| **52mm x 80mm** | Holds TeleVue Radians, Nagler 6, most Barlows, large Celestron Ultimas, etc. | **\$3$^{49}$** |
| **65mm x 80mm** | Holds most illuminated reticles, 22mm Panoptic, 12mm Nagler, etc. | **\$3$^{99}$** |

> The information you provide on your website for "How to pick a telescope" is outstanding. I'm still taking it all in, but so far the information has been very understandable, clear, and thorough. Thank you.
>
> **Customer Quote of the Month #133**

## The new Celestron Modular i Series 8" GPS SCT starts at only \$1199!

NexStar 8i

**\$1199**

shown with optional tripod and computer

CELESTRON

If you compare prices and specs, you'll see that the **Celestron NexStar 8i** go-to costs less than other comparably-equipped 8" scopes. Starting at only \$1199 for a complete working dual-axis drive scope, you can add the options that you, and your budget, feel comfortable with. An *iCOMP* computer hand control with 40,000 deep space objects in memory is \$149. A lightweight travel tripod is \$149. A heavy duty tripod (same as the NexStar 11 GPS) is \$299. If you want the convenience of GPS auto-alignment, add it for only \$199. No matter how you outfit your NexStar 8i, it's enough scope to keep you observing for the rest of your life, at a price that leaves other scopes behind.

## A whole lot less shaking going on!

Canon

*Sky & Telescope* said that hand-holding Canon image-stabilized binoculars was "truly a quantum leap in binocular observing," Canon images are rock-solid, not jittery, no matter how unsteady your hands. You'll see more detail than with conventional binos. There are big 15 x 50mm and 18 x 50mm models excellent for astronomy. Full details are on our website.

## Sell your used telescopes and accessories quickly by using the classified ads you can run *for free* at

## www.astrofieds.com

## The Stellarvue refractor is a "hot new product."

AT1010A **\$499$^{95}$**

shown w/optional diagonal and eyepiece

The 80mm f/6 **Stellarvue AT1010** achromatic refractor was named a "Hot New Product" in the December 2001 issue of *Sky & Telescope*. Even better, independent reviews say it competes favorably with ED semi-apochromatic scopes that cost twice its modest price, and that it easily outperforms imported achromatic scopes in color correction and resolution. The AT1010CN has triple tested hand-assembled optics, tube rings, a tripod adapter, a 2" focuser with 1.25" adapter and T-threads, red dot finder, oversize rubberized focus knobs for easier use in cold weather, and a soft padded carry case. It's a super deal and it's in stock to ship now. It's one of several Stellarvue refractors we keep in stock, in apertures from 78mm to 102mm, *including APOs*.

## Discovery Dobs are not cheap . . . just inexpensive.

8" f/6 DHQ

**\$449**

Why settle for an imported Dob when you can have made-in-the-USA quality *for less money!* Discovery doesn't use inexpensive, imported, mass-produced optics that are only spot-checked to see if they're acceptable. Discovery optics are made in California by optical craftsmen, one quality mirror at a time. Each is hand figured to diffraction-limited performance, and it doesn't leave the Discovery optical shop until it's right.

Each DHQ series Dob has an adjustable metal primary mirror cell, a true *thin vane* adjustable 4-vane diagonal mirror spider, *two* Plössl eyepieces, a built-in tube balancing system, a tube carry handle, new oversized bearings, a 6 x 30mm finder, and a dust cover. For only \$49 more, you can get an upgrade kit that adds two more Plössl eyepieces, an eyepiece rack, a second dust cover, and a Moon filter!

Premium Dobs are also available in 10" to 17.5" apertures. And for those who need portability, easy set-up and take-down truss-tube Dobs are available in apertures of 12" to 24". Here are the 6" to 10" Discovery DHQ Dob prices:

| | | |
|---|---|---|
| 6" f/5 Discovery DHQ | **\$339$^{00}$** | plus \$49 freight |
| 6" f/8 Discovery DHQ | **\$339$^{00}$** | plus \$49 freight |
| 8" f/6 Discovery DHQ | **\$449$^{00}$** | plus \$49 freight |
| 8" f/7 Discovery DHQ | **\$449$^{00}$** | plus \$49 freight |
| 10" f/4.5 Discovery DHQ | **\$649$^{00}$** | plus \$69 freight |
| 10" f/5.6 Discovery DHQ | **\$649$^{00}$** | plus \$69 freight |

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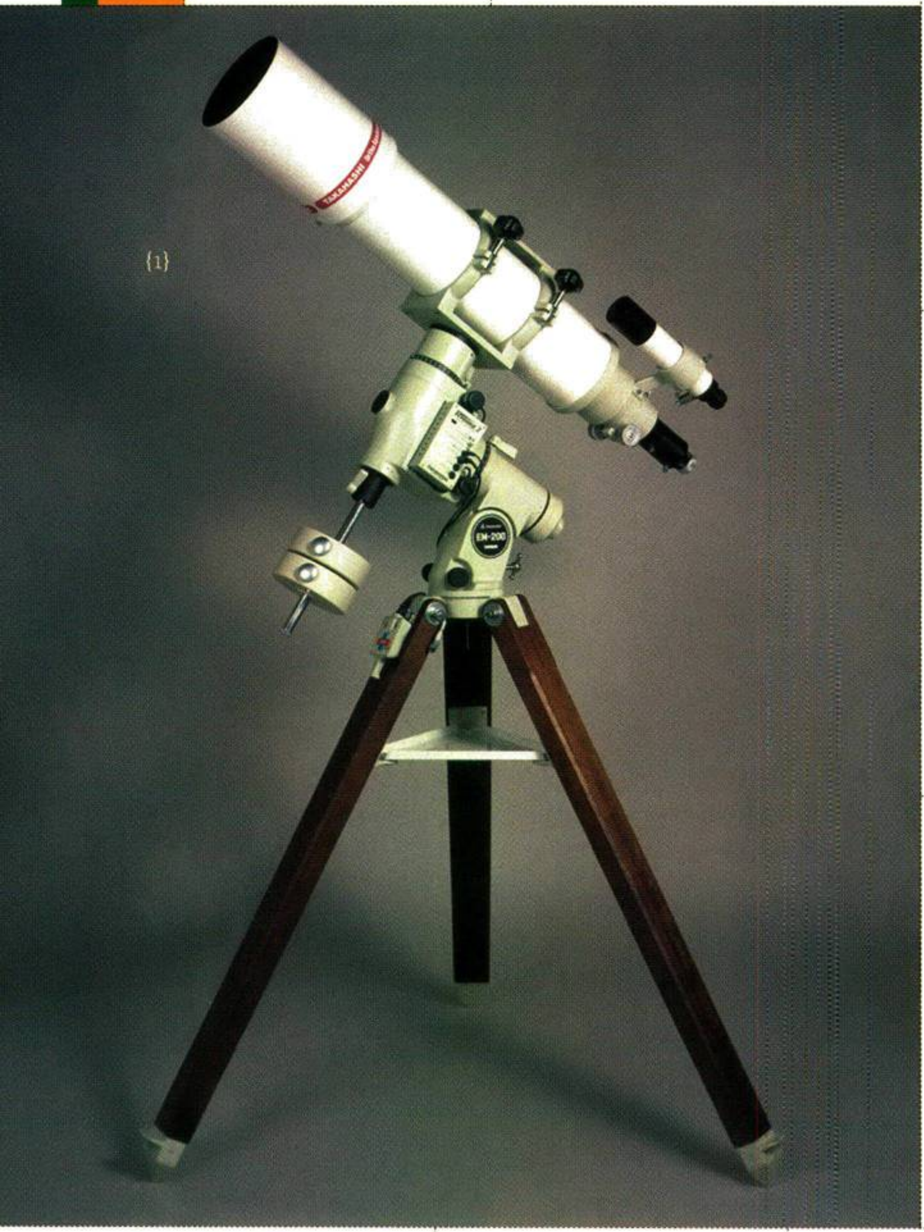
{1}

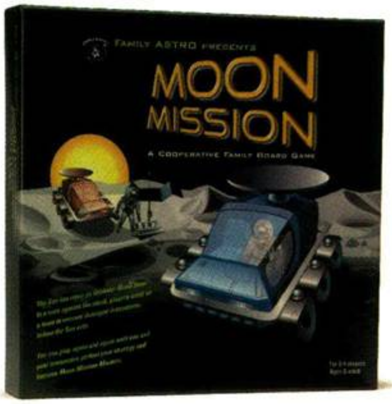


{2}

{3}

UltraWide 9mm
UltraWide 6mm Long Eye
UltraWide 15mm Long Eye
Multi-Coated

{4}



**1. Takahashi TOA-130**
Telescopes, like books, should not be judged by their covers. Although the Takahashi TOA-130 looks like other scopes on the market, it's quite different. The first of its kind, this 1,000mm focal length "Ortho-Apochromat" uses three lenses and several light baffles to produce sharp, true-color images. CCD or film cameras, filter wheels, and focusers can be attached to the f/7.7 scope.

$5,000; Texas Nautical Repair Co.
3110 S. Shepherd Drive
Houston, TX 77098
[t] 713.529.3551
[w] www.lsstnr.com

**2. Swarovski ATS 80 spotting scope**
The Swarovski ATS 80 is proof that good things do come in small packages. About a foot long and weighing less than three pounds, this versatile spotting scope can be toted to star parties or, for those so inclined, used underwater to a depth of 13 feet. The f/4.4 scope offers rubberized armoring, a removable aiming aid, and a large focusing ring. An eyepiece is available for $250.

$1,099 without eyepiece
Swarovski Optik N.A.; 2 Slater Road
Cranston, RI 02920
[t] 800.426.3089
[w] www.swarovskioptik.com

**3. Pro-Optic 1¼" eyepieces**
These Pro-Optic eyepieces from Adorama provide panoramic vistas of the night sky. Available in 6mm, 9mm, 15mm, or 20mm sizes, the ultra-wide lenses boast 66° fields of view. The outer lenses are multi-coated, and the barrels are blackened to maximize light transmission. For a range of views, try Pro-Optic's 7mm to 21mm zoom eyepiece, which spans from 30° to 43°.

$49.95 per ultra-wide eyepiece;
$59.95 for the zoom; Adorama
42 W. 18th St.; New York, NY 10011
[t] 800.223.2500
[w] www.adorama.com

**4. *Moon Mission***
Bored of board games set in the confines of our home planet? Try *Moon Mission*, the latest offering from the Astronomical Society of the Pacific's Family ASTRO program, designed to spark interest in the science of the stars. In the game, players strategize together on how to recover damaged instruments littered across the Moon before the long lunar night descends.

$15.95
Astronomical Society of the Pacific
Online sales only
[w] www.astrosociety.org/online-store/scstore/

# Join the editors of *Astronomy* magazine on an astronomy tour of HAWAII!

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- Inside tour of some of the biggest telescopes in the world
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- Enjoy two private visits to the summit of Mauna Kea
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- Five nights in Hilo, Hawaii
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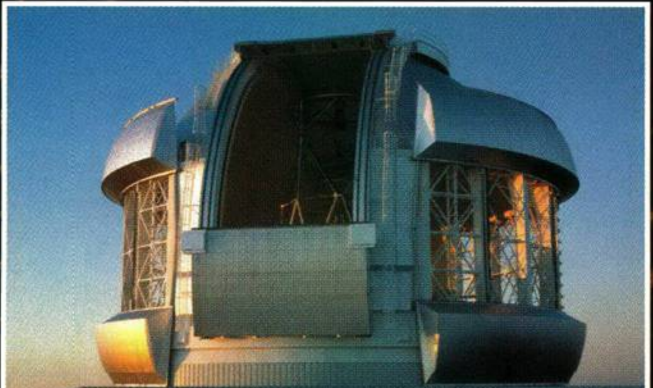

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*Exquisite, Diffraction-Limited Imaging in an advanced, ultra portable telescope system!*

**ETX-90EC Includes:**
w/Dual-Axis Drive,
8x21 Erect-Image Viewfinder
& 26mm Plossl

**ETX- 125EC Includes:**
Dual-Axis Drive,
8x25 Right-Angle Viewfinder
& 26mm Plossl

**Optional #497 Autostar** controller with GO TO capability **$149**

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| **ETX 70 AT** 70mm (2.8") 350mm f/5 w/tripod | $349 |
| **ETX 90EC** 1250mm f/13.8 | $494 |
| **ETX 90EC** 1250mm f/13.8 w/UHTC | $545 |
| **ETX 105EC** | $695 |
| **ETX 105EC** w/UHTC | $799 |
| **ETX 125EC** 1900mm f/15 | $895 |
| **ETX 125EC** 1900mm f/15 w/UHTC | $990 |
| **#883** Deluxe ETX Field Tripod (90/105/125) | 179 |
| **#884** Deluxe ETX Field Tripod (90/105/125) w/carrying bag | 199 |
| **#64** Photo Adapter f/ETX (90/125) | 34.95 |
| **#825** 8x25 Right-Angle Viewfinder (90) | 49.95 |
| **#880/#881** Equatorial Table Tripod (90/125) | 29.95/59.95 |
| **#932** 45° Erecting Prism (90/125) | 49.95 |
| **#1244/#1247** Electric Focuser (90/125) | 119.95 |
| **#773, #774, #775 ,#776** Hard Case for ETX | CALL |

## PICTOR CCD IMAGERS 416-XTE & 1616-XTE

*With New Kodak Blue-sensitive CCD Chip*

*For the beginner, or for the most advanced observer, the real CCD revolution is here!*

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| **201-XT** Autoguider/Imager | 395 |
| **208-XT** Autoguider/Imager | 495 |
| **216-XT** Autoguider/Imager | 695 |
| **416-XTE** Autoguider/Imager | 1,995 |
| **1616-XTE** Autoguider/Imager | 6,495 |
| Off Axis Guider f/CCD | 89.95 |
| **616** Color Filter System f/416, 1616-XT | 695 |
| **616A** Color Filter System f/216 | 695 |
| **520** Electronic Relay f/201, 208, 216, 416, 1616 | 94.95 |
| **541** AC Adapter f/201, 208, 216 | 36.95 |
| **542** AC Adapter f/416, 1616 | 94.95 |

## EYEPIECES

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### PLOSSL SERIES 3000

| | | | |
|---|---|---|---|
| 5, 6.7, 9.5, 16, 25mm 1.25" | 49.95 | 40mm 1.25" | 79.95 |

### SUPER PLOSSL SERIES 4000

| | | | |
|---|---|---|---|
| 6.4, 9.7, 12.4, 15, 20, 26mm 1.25" | | | 79.95 |
| 32, 40mm 1.25" | 99.95 | 56mm 2" | 199.95 |

### PLOSSL SERIES 4000 SUPER WIDE ANGLE

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|---|---|---|---|
| 13.8mm 1.25" | 139.95 | 18mm 1.25" | 149.95 |
| 24.5mm 1.25" | 179.95 | 40mm 2" | 299.95 |
| 32mm 2" | | | 239.95 |

### PLOSSL SERIES 4000 ULTRA WIDE ANGLE

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|---|---|---|---|
| 4.7mm 1.25" | 169.95 | 8.8mm 1.25"/2" | 239.95 |
| 6.7mm 1.25" | 199.95 | 14mm 1.25"/2" | 299.95 |

### ILLUMINATED RETICLE EYEPIECE SYSTEMS

| | Wireless | w/Cord |
|---|---|---|
| Plossl 9mm 1.25" | 149.95 | 129.95 |
| MA 12mm 1.25" | 99.95 | 79.95 |
| MA 12mm Astrometric 1.25" | | 119.95 |
| Plossl 25mm CCD Framing Ocular 1.25" | | 129.95 |

### BARLOWS

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|---|---|
| **#122** 2x Telenegative 1.25" | 44.95 |
| **#126** 2x Short Focus 1.25" | 44.95 |
| **#127** 2x-3x Variable 1.25" | 56.95 |
| **#134** Achromatic .96" | 44.95 |
| **#140** 2x Apochromatic 1.25" | 74.95 |

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Standard-equipment includes:
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- GO TO pointing position
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- Auto-Star II hand controller accesses 125,000 object database

| | |
|---|---|
| **LX-90 8"** f/10 | CALL FOR LOW PRICE |
| **LX-90 8"** f/10 w/UHTC | CALL FOR LOW PRICE |
| **LX-10 8"** w/wedge & tripod | $995 |
| **LXD 300 SERIES 203** 8" f/10 | $795 |
| **LXD 500 SERIES 203** 8" f/10 | $895 |
| **LX-200 GPS 7"** Maksutov-Cassegrain | $2,995 |
| **LX-200 GPS 7"** Maksutov-Cassegrain, w/UHTC | $3,145 |
| **LX-200 GPS 8"** | CALL FOR LOW PRICE |
| **LX-200 GPS 8"** w/UHTC | CALL FOR LOW PRICE |
| **LX-200 GPS 10"** | CALL FOR LOW PRICE |
| **LX-200 GPS 10"** w/UHTC | CALL FOR LOW PRICE |
| **LX-200 GPS 12"** | CALL FOR LOW PRICE |
| **LX-200 GPS 12"** w/UHTC | CALL FOR LOW PRICE |
| **LX-200 GPS 14"** | $4,295 |
| **LX-200 GPS 14"** w/UHTC | $4,695 |
| **LX-200 GPS 16"** | CALL |

## ED APO REFRACTORS

### 300 SERIES

| | |
|---|---|
| **102 Achromatic** 4" f/9 | $549 |

### 500 SERIES

| | |
|---|---|
| **102 Apochromatic** 4" f/9 | $1,599 |
| **102ED 4"** f/9 w/Mount, Tripod & Acc. | $2,795 |
| **127ED 5"** f/9 w/Mount, Tripod & Acc. | $3,295 |
| **152ED 6"** f/9 w/Mount, Tripod & Acc. | $4,995 |
| **178ED 7"** f/9 w/Mount, Tripod & Acc. | $5,995 |

| | |
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| Optical Tube Only | CALL |
| **#1207** Electric Focuser | 144.95 |
| **#1664** Electronic Drive | 349 |
| **#1697** Computer Drive System | 749 |
| **#1702** Dual Axis Drive System | 195 |
| **#1812** Electronic DC Adapter | 89.95 |

## ACCESSORIES

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| **#931** 45° Hybrid Erct Prsm | 43 | f/6.3 Focal Reducer | 129.95 |
| Basic Tele-Extender | 29.95 | **#1205** Focuser | CALL |
| Camera Adapter 1.25" | 29.95 | **#1206** Focuser | CALL |
| Camera Adapter .96" | 27.95 | 6x30 Viewfinder | CALL |
| Variable Tele-Extender | 39.95 | 8x50 Viewfinder | CALL |
| DEW SHIELD & DUST COVER | Call | **#607** 25' Cigarette Adpt | 25 |
| Piggyback Bracket f/SCT | Call | 55 Manual DEC Control | 75 |

| | |
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| Variable Projection Camera Adapter 1.25" | 39.95 |
| **#927** 45° Erect Image Diagonal Prism .96" | 42.95 |
| **#928** 45° Erect Image Diagonal Prism 1.25" | 42.95 |
| **#929, #930** 2" Mirror Diag. w/Eyepiece Holder f/1.25" | 99.95 |
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| **#531** Motor Drive w/Auto Tracking f/4500 Newtonian | CALL |
| Interface Cable f/LX-200 | 25 |
| **EPOCH 2000sk** Sky Software 3.5" Disks | 149 |
| **EPOCH 2000sk** Sky Software CD | 179 |
| **EPOCH 2000ip** Software 3.5" Disks | 199 |

## FILTERS

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|---|---|---|---|
| **#905** Variable Polarizer 1.25" | | | 49.95 |
| Moon Filter ND96 1.25" | 19.95 | 4 Piece Set 1.25" | 49.95 |
| Individual Filters | 14.95 | Skylight/Dust Seal | 44.95 |

| * Nebular | Oxygen III | Broadband* | Narrowband* |
|---|---|---|---|
| **#908** 1.25" | 99.95 | 79.95 | 89.95 |
| **#910** 2" | 159.95 | 119.95 | 129.95 |
| **#911** Rear Cell | 149.95 | 99.95 | 119.95 |

## LXD55

Now you can buy a Schmidt-Newtonian telescope with Autostar dual-axis GO TO drive system for $695

**Featuring:**
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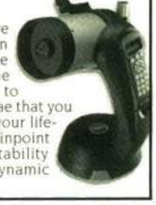

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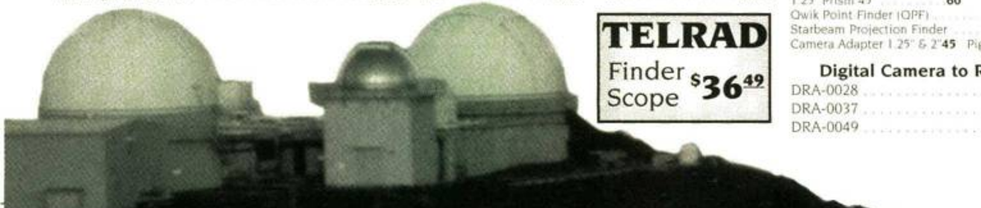

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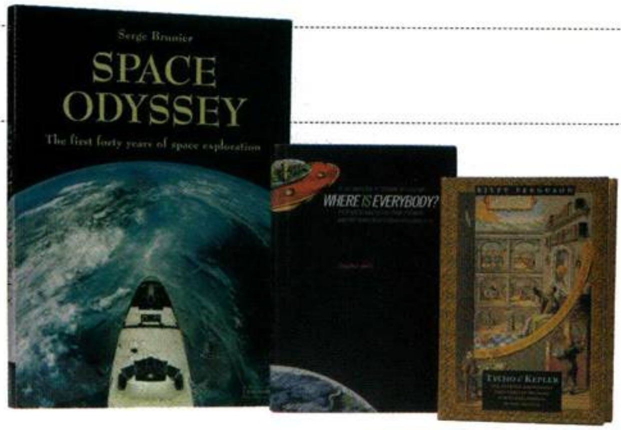


# Quest for a cosmic connection

### *Space Odyssey: The first forty years of space exploration*

Serge Brunier, 192 pages, Cambridge University Press, New York, 2002; ISBN 0-5218-1356-5; hardcover, $40.

Just when you think you've seen every incarnation of a space picture book imaginable, along comes a new treatment that provokes a different perspective. French journalist Serge Brunier has produced a coffee table book of images from four decades of space flight. But what sets Brunier's effort apart from other similar works is his, well, French perspective. He views space exploration rather romantically, linking the adventure that so consumed the technocrats of the United States and the Soviet Union with humanity's desire to understand both its surroundings and itself.

*Space Odyssey* reproduces in lush color many familiar images of spaceships, shuttles, and natural cosmic wonders snapped by orbiting craft over the generations. Several images from the Hubble Space Telescope grace the book's pages, including a two-page spread in which every inch sparkles with stars. But Brunier has also sought out the unusual and the rarely seen. Among those striking images are a lone Soyuz rocket ascending toward orbit, almost lost in a gray dawn, and a single occupant of the Mir station jammed into an area literally filled to the rafters with mission paraphernalia.

The book is divided into seven sections, and tables list every one of the 397 men and women who blazed the trail into space from 1961 to 2001. Brunier also includes charts of Apollo mission flight profiles, a map of the lunar surface, a chronology of various space missions, and a bibliography of space books.

At one point, Brunier recounts a summer afternoon in 1994 when he played host to visiting Apollo 11 astronaut Buzz Aldrin, in France for a television documentary about his historic lunar flight. To Brunier's surprise, Aldrin seemed weary of recounting his space mission heroics and, when waxing poetic about the Moon voyage, exhibited an unusual blend of "sweet bitterness close to bliss." It was then Brunier saw space exploration as a grand expression of human achievement — the astronauts seemed less heroes than ambassadors to a new age. Brunier explains: "Neither superbeings nor robots, they would reveal all their frailty and humanity in the years to follow the Homeric adventure they had helped to write." Not your typical space book, indeed. — **FRANK SIETZEN** *is the editor-in-chief of* Ad Astra *magazine and a writer and analyst specializing in space flight in Arlington, Virginia.*

### *Where Is Everybody? Fifty Solutions to the Fermi Paradox and the Problem of Extraterrestrial Life*

Stephen Webb, 304 pages, Copernicus, New York, 2002; ISBN: 0-3879-5501-1; hardcover, $27.50.

During a lunchtime discussion more than fifty years ago, four prominent scientists from Los Alamos National Laboratory — Edward Teller, Herbert York, Emil Konopinski, and Enrico Fermi — concluded that advanced extraterrestrial civilizations have to exist. The size and age of the universe demand it. In the same conversation, Fermi asked, "If the universe is teeming with advanced extraterrestrial civilizations, where is everybody?" Famous for his back-of-the-envelope calculations, the world-class physicist had reasoned that we should have been visited long ago — and many times over — yet there was no evidence for any such visits. In *Where is Everybody?*, Stephen Webb, a physicist at England's Open University and the author of *Measuring the Universe: The Cosmological Distance Ladder*, examines proposed solutions to this conundrum, known as the Fermi Paradox.

Webb begins with a brief but enlightening biography of Enrico Fermi, focusing primarily on his scientific achievements. He then discusses the notion of a paradox, including those of Zeno and Olbers. Arguing from the Principle of Mediocrity, i.e. that there is nothing special about Earth or the solar system, many scientists since Fermi have determined we should have some proof of extraterrestrial civilizations (ETCs) in the form of visits, communications, or technological relics.

Webb discusses his 49 favorite solutions to the paradox and in the final chapter presents his own, not entirely new, interpretation of its resolution. The solutions fall into three broad catagories: (1) aliens are already among us, (2) aliens exist but have not yet communicated, and (3) aliens do not exist. The proposed solutions range from highly plausible to absolutely crackpot, but they are well explained, and Webb skillfully argues their pros and cons with science. He constantly grounds the reader with the Principle of Mediocrity and the guiding logic of Occam's razor, which requires the simplest among competing theories to be used.

*Where is Everybody?* is a delightful mental romp. With a light-hearted, enthusiastic tone, Webb offers lively coverage of UFOs, crop circles, and the books of Erich von Däniken, the infamous proponent of the idea that aliens visited Earth in the distant past. Science-fiction fans will enjoy frequent references to *Star Trek*, and science buffs will appreciate mention of the ideas of Carl Sagan, Fred Hoyle, Frank Drake, and Freeman Dyson. This book is a must-read for anyone who has ever pondered the question, "Are we alone?" — **JENNIFER BIRRIEL** *teaches physics at Morehead State University in Morehead, Kentucky.*

### *Tycho & Kepler: The Unlikely Partnership that Forever Changed Our Understanding of the Heavens*

Kitty Ferguson, 288 pages, Walker & Co., New York, 2002; ISBN 0-8027-1390-4; hardcover, $28.

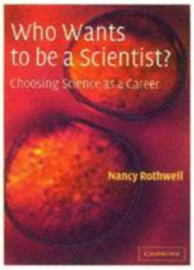
In Kitty Ferguson's new book, readers follow the lives of two of the greatest astronomers of all time — the eminent, arrogant Danish stargazer Tycho Brahe and the passionate, young Austrian mathematician Johannes Kepler. In what Ferguson sees as an almost mystical turn of fate, the dynamic duo were brought together in Prague, where Kepler became Brahe's combative assistant.

Both the aristocratic Tycho and his brilliant aide were committed to astronomy with unbounded devotion. Tycho sometimes sounds like an egomaniac; Kepler occasionally sounds simply mad: "I yield to the sacred frenzy . . . I can wait a century for a reader, as God himself has waited six thousand years for a witness." Kepler's narcissistic outburst turned out to be the simple truth of the matter.

Although Tycho was the elder mentor in their relationship, Kepler didn't always follow his lead. On his deathbed, Tycho asked Kepler to build on his Earth-centered explanation of the cosmos. But Kepler never complied. Instead, he pursued their predecessor Copernicus's convictions, which were later vindicated by Kepler's own laws of planetary motion. As Galileo remarked, "[Kepler] had the motions of the Earth at his fingertips."

Ferguson, following a rarely questioned view, takes for granted that Kepler needed Tycho's results to formulate his own principles. Yet Kepler was well on the way to his laws before he ever saw Tycho's data. In fact, as Harvard historian of science Owen Gingerich has shown, the seeds of Kepler's laws seem to have been sown in a seemingly unrelated law by the ancient Greek astronomer Ptolemy. Given the extraordinary intensity and ingenuity Kepler repeatedly displays, whether Kepler really needed Tycho should be an open question.

This is popular history in the mode of Dava Sobel's hugely successful *Longitude* and *Galileo's Daughter*. While Ferguson is not as elegant a writer as Sobel, her more detailed treatment of the technical side of Kepler's work amply compensates. Some insight into that technical work is essential to grasp why Kepler is such a remarkable figure in the history of science. — **HOWARD MARGOLIS** *gives a new account of the scientific revolution in his book* It Started with Copernicus *(McGraw-Hill, 2002).*



### *Who Wants to be a Scientist? Choosing Science as a Career*

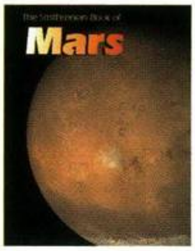
Nancy Rothwell, 166 pages, Cambridge University Press, New York, 2002; ISBN 0-5215-2092-4; softcover, $21.

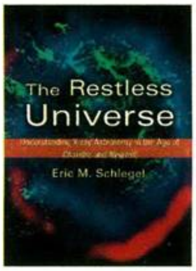
Despite its impersonal objectives, science is a distinctly human endeavor, with its own culture and mores. In this guidebook, Rothwell, herself a physiologist, lays bare the obstacle course to becoming a scientist, from the need to publish (or perish) to giving effective presentations. Whether you're considering a career in science or are already committed to the field, *Who Wants to be a Scientist?* can help you realize your dreams.

### *The Smithsonian Book of Mars*

Joseph M. Boyce, 321 pages, Smithsonian Institution Press, Washington, D.C., 2002; ISBN 1-5883-4074-0; hardcover, $34.95.

From its fabled canals to the tantalizing evidence of fossilized life on a martian meteorite, Mars has long captured our imaginations. In this comprehensive volume, Joseph Boyce, NASA's Mars exploration program scientist from 1985 to 2000, describes what we know of the planet's atmosphere, surface, and interior from observations and nearly 40 years of space probes. Color photographs, illustrations, and a glossary make the book an appealing read and an accessible reference.





### *The Restless Universe: Understanding X-ray Astronomy in the Age of Chandra and Newton*

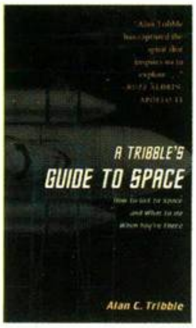
Eric M. Schlegel, Oxford University Press, New York, 2002; ISBN 0-1951-4847-9; hardcover, $30.

Not so long ago, we were restricted to viewing the universe in the optical. But gradually, we have been drawing back the curtain on other realities, developing instruments sensitive to a wide range of wavelengths. Astrophysicist Eric Schlegel introduces us to the brave new world of x-ray astronomy in this book, which delves into recent discoveries using the spacecraft Chandra and Newton.

### *A Tribble's Guide to Space: How to Get to Space and What to do When You're There*

Alan Tribble, Princeton University Press, Princeton, New Jersey, 2002; ISBN 0-6910-2763-3; softcover, $16.95.

With chapter titles such as "To Infinity and Beyond" and "Beam Me Up," this whimsical book describes the physics and history of leaving our home planet and the motivation behind the endeavor. With a light, winning tone, author Alan Tribble writes from an insider's perspective — the rocket scientist has helped design dozens of spacecraft over the past ten years.



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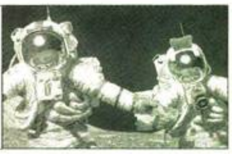

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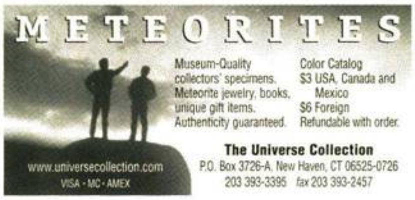

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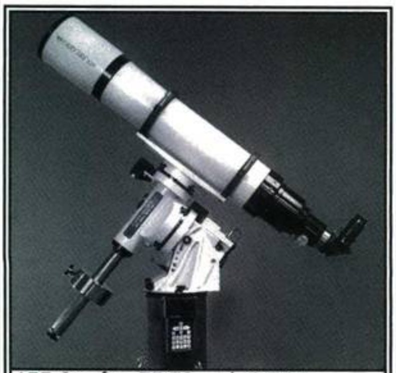

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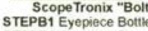

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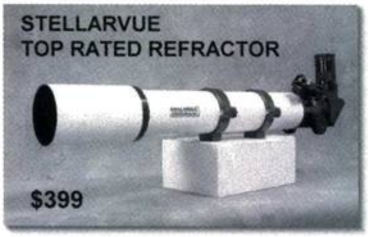

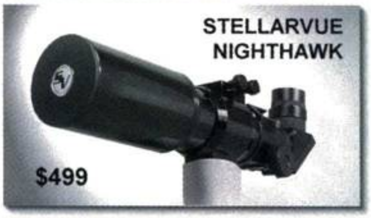

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# RESOURCES

Learn more about this issue's topics

### CENTAURUS AND ANTLIA

**BOOKS —** If your telescope or binoculars frequently aim south of the celestial equator, keep by your side a copy of the southern-sky star atlas *Uranometria 2000.0 Volume II: The Southern Hemisphere to +6°*, edited by Wil Tirion, Barry Rappaport, and George Lovi (Willmann-Bell, Richmond, Virginia, 1988).

For a complete list of NGC and IC objects throughout the sky, refer to *NGC 2000.0: The Complete New General Catalogue and Index Catalogues of Nebulae and Star Clusters by J. L. E. Dreyer*, edited by Roger W. Sinnott (Sky Publishing, Cambridge, Massachusetts, 1997).

For a descriptive guide of what deep-sky objects and other wonders you can find in the night sky, take a look at *Burnham's Celestial Handbook* by Robert Burnham (Dover Publications, New York, 1978). Its three volumes organize the constellations alphabetically, so pick up Volume 1 for Centaurus and Antlia.

### COMPACT GALAXY GROUPS

**BOOKS —** Find all 100 known compact groups with cataloger extraordinaire Paul Hickson's *Atlas of Compact Groups of Galaxies* (Gordon & Breach, Basel, Switzerland, 1994).

**ARTICLE —** Also by the man who put the "Hickson" in "Hickson Compact Groups" is a scientific review of the objects in "Compact Groups of Galaxies" (*Annual Reviews of Astronomy and Astrophysics*, vol. 35, pp. 357–388, 1997).

**WEB —** To find the complete Hickson catalog of compact groups, go to http://archive.ast.cam.ac.uk/viz-bin/VizieR and search on the keyword "Hickson" or the catalog "VII/213."

### ECLIPSE

**BOOKS —** For tips on planning an eclipse expedition, details on what you can see during an eclipse, and a summary of each central solar eclipse until 2020, see *Chasing the Shadow: An Observer's Guide to Eclipses* by Joel Harris and Richard Talcott (Kalmbach Publishing, Waukesha, Wisconsin, 1994).

*Annular and Total Solar Eclipses of 2003*, NASA Technical Publication TP–2002–211618, provides a comprehensive overview of the annular eclipse in May and the total eclipse in November. Single copies are available at no cost and may be ordered by sending a 9" by 12", self-addressed stamped envelope with sufficient postage for 12 ounces to Fred Espenak, NASA/GSFC, Code 693, Greenbelt, MD 20771.

**WEB —** Fred Espenak provides general information on every solar and lunar eclipse between 1951 and 2050 at the NASA Eclipse Home Page, http://sunearth.gsfc.nasa.gov/eclipse/eclipse.html.

### THE GOLDEN RATIO

**BOOKS —** For a more in-depth view of the Golden Ratio's history and its significance throughout the sciences, read *The Golden Ratio: The story of phi, the world's most astonishing number* by Mario Livio (Broadway Books, New York, 2002). Modern translations of Euclid's *Elements* (Dover Publications, Mineola, New York, 1989), and Ptolemy's *Almagest* (Princeton University Press, Princeton, New Jersey, 1998), are also available.

**WEB —** Detailed mathematical discussions of all the topics addressed in this story — including the Golden Ratio, Fibonacci numbers, and Penrose tiles — can be found online in Eric Weisstein's World of Mathematics at http://mathworld.wolfram.com.

### MAUNA KEA

**BOOKS —** For more information about the wealth of observing on Mauna Kea, see Barry Parker's *Stairway to the Stars: The Story of the World's Largest Observatory* (Perseus, Cambridge, Massachusetts, 2001). The book includes interviews with some of the on-site astronomers and lists major discoveries made on the mountain. If you decide to make a pilgrimage to the islands, consider buying *Stars over Hawaii* by Edwin H. Bryan (Petroglyph Press, Hilo, Hawaii, 2002). The book contains monthly star charts, drawings, and stories about the constellations.

**WEB —** Take virtual tours of Hawaii's main telescopes at their detailed websites. For the Canada-France-Hawaii Telescope, go to www.cfht.hawaii.edu; for Subaru, check out www.naoj.org; for Gemini, visit www.gemini.edu; and for the Kecks, see www2.keck.hawaii.edu. To learn more about Native Hawaiian groups fighting the construction of more telescopes on Mauna Kea, see www.honoluluweekly.com/archives, click on "coverstory 2002," then click on "03-27-02 Mauna Kea."

### VARIABLE FILTER SYSTEM

**BOOK —** Using Sirius Optics' VFS 1.25 can bring out subtle hues in planetary targets. Pick up the second edition of *The Planet Observer's Handbook* (Cambridge University Press, Cambridge, United Kingdom, 2000) by Fred Price for an informative guide to the solar system. Perfect for any amateur interested in viewing or imaging planets, this book provides tips and techniques to make observing experiences more entertaining and productive. This guide is suitable for use at home or in the field.

### VESTA

**BOOKS —** A good background on asteroids, from their discovery two centuries ago to the latest thoughts on how to avert possible devastating impacts, can be found in *Asteroids: A History* by Curtis Peebles (Smithsonian Institution Press, Washington, D. C., 2000).

**WEB —** Ephemerides and magnitude estimates for the brightest asteroids visible during 2003 are located at http://cfa-www.harvard.edu/iau/Ephemerides/Bright/2003/index.html.

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**04.26.03–05.04.03**

## Thoughts of traveling to Hawaii

usually conjure visions of crashing waves and basking in sunlight on immaculate beaches. The *Astronomy* tour of Hawaii will certainly provide this and many more idyllic scenarios in this island paradise. The tour begins in Honolulu with a visit to the USS *Arizona* memorial followed by a visit to the Battleship USS *Missouri*. The following two days will be open for touring the Hawaiian destinations of your choice.

**THE OBSERVATORIES** at the summit of Mauna Kea will be a highlight for astronomy enthusiasts visiting Hawaii. MAYHUGH TRAVEL

Next, the group will fly to the Big Island, home to the observatories of Mauna Kea. From Hilo, the excursion will travel to Mauna Kea to inspect some of the largest and most sophisticated telescopes in the world, including the Keck telescopes and the Gemini North facility. Following evening meals on these nights, guests will step outside to view the night sky using a variety of scopes.

*Astronomy* editor Dave Eicher will accompany the tour, providing insight on the night sky and destinations.

For more information, contact Mayhugh Travel at 701 Perdew Avenue, Ridgecrest, CA 93555; phone, 888.412.5317 (outside of the U.S., 760.446.0050); website, http://astronomyvacations.com.

**03.29.03**

### Lake Whitney Astronomy Day Celebration

Lake Whitney State Park, Whitney, Texas. The day-long event will feature observing, amateur telescope making, guest speakers, door prizes, and awards. For more information, contact Thomas Williamson, Lake Whitney Astronomy Association, 7005 Southampton, North Richland Hills, Texas 76180-4433; website http://whitney-astro.com/.

**04.19.03**

### StarConn

Wesleyan University, Middletown, Connecticut. The Astronomical Society of Greater Hartford will be celebrating its 17th annual StarConn with speakers, demonstrations, vendors, and swap tables. For more information, contact the ASGH at asgh2001@hotmail.com or Scott Tracy at vega154@cox.net; website, www.asgh.org.

**04.23.03–04.26.03**

### Mid-South Star Gaze

Rainwater Observatory, French Camp, Mississippi. The Mid-South Star Gaze is a weekend for amateurs to gather and observe together. For more information, visit the Rainwater Observatory's website, www.rainwaterobservatory.org/.

**04.25.03–04.26.03**

### NIAGfest

Camp Crosley, North Webster, Indiana. Co-sponsored by the Northern Indiana Astronomical Group and the Great Lakes Region Astronomical League, NIAGfest is a weekend of camping and observing. For more information, contact Mike Beaver at 574.834.5953 after 5 P.M. EST; e-mail, michaelbeaver@kconline.com; website, http://www.clubs.kconline.com/was/niag.htm.

**04.27.03–05.03.03**

### Texas Star Party

Prude Ranch, Fort Davis, Texas. Daytime and nighttime observing will once again highlight the Texas Star Party. Other activities include tours of the McDonald Observatory, lectures, horseback riding, workshops, and a swap meet. For more information, visit the Texas Star Party's website, http://www.metronet.com/-tsp/.

**05.01.03–05.04.03**

### MACE 2003

Mallorca Observatory, Mallorca, Spain. The Meeting on Asteroids and Comets in Europe will focus on minor bodies traveling through our Solar System, as well as advances in observing techniques and telescope technology. For more information, visit MACE's website, www.oam.es/oam/mace/intro.htm.

**CONTACT INFORMATION**

Please submit club announcements four months in advance to Coming Events, *Astronomy*, P. O. Box 1612, Waukesha, WI 53187, or jmcgovern@astronomy.com. Add your events to our online calendar at http://www.astronomy.com.

# INDEX *of* ADVERTISERS

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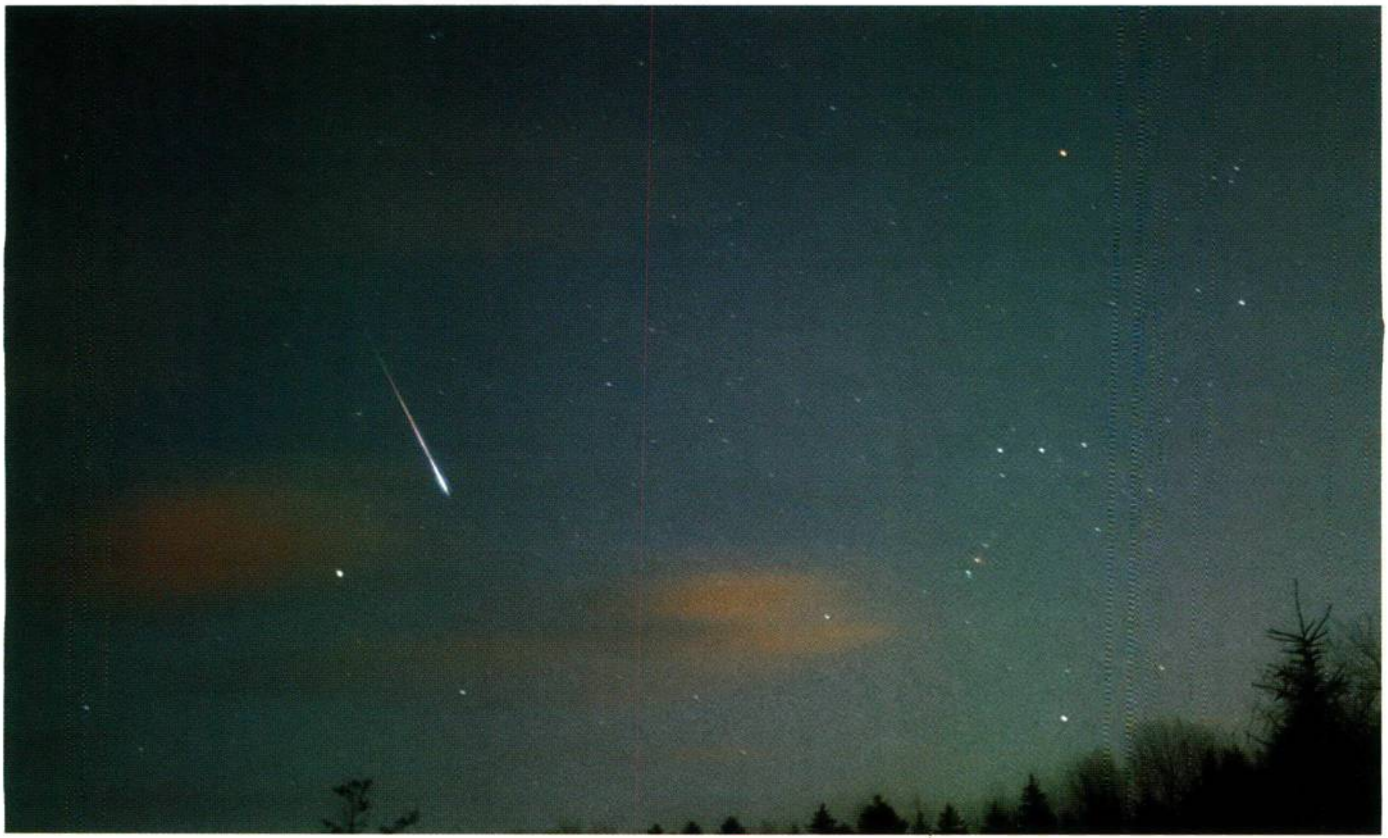
Adorama 32,33
Analytical Scientific 105
Astro Physics 108
Astronomics 40
Astronomy Binders 37
Astronomy Camp-Camp Eberhardt 105
*Astronomy* Magazine 110,115
Atomic Time 28
Bennett Book Advertising 103
Berger Brothers Camera 105
Beta Electronics 105
Binoculars.com 109
Bob's Knobs 106
Cambridge University Press 37
Camera Bug 106
Celestron International 24,25,26,27,38,39
Century 21 1st American 105
Dark Sky Inc. 106
Davis Instruments 79
Denkmeier Optical 106
Focus Camera 112
Galactica 360 109
Galapagos Island Tour 32
Gauntlet Books 108
Glatter, Howard 107
Hardin Optical Co. 108
Hawaiian Astronomy Tour 101
Into the Wind/The Kite Source 109
Jim's Mobile Industries 74
JMB, Inc. 79
Kendrick Astro Instruments 23
Kitt Peak National Observatory 79
Kowa Optimed Inc. 99
Learning Technologies Inc 109
Mag One Instruments 105
Marketplace Pages 105,106,107,108,109
Mayhugh Travel 106
Meade Dealer Pages 12, 13
Meade Instruments Corp. 2,3,7,8,9,10,11,122
Mountain Skies Astronomical Society 108
National Academy Press 28
New Mexico Skies 108
Newport Glass Works 109
Nisur Systems 106
Nite I's Inc. 109
Northern Lights Tour 103
Novaspace 105
Observatory Inc.,The 107
Oceanside Photo & Telescope 23
Orion Telescopes & Binoculars 70-71,121
Owl Services 107
Questar Corporation 32
Rainbow Symphony 23
RITI 28
Ritz Camera Superstores 108
Rivers Camera Shop 74
SAC Imaging Systems 109
SCS Astro 108
Santa Barbara Instrument Group 17
Science Connection 108
Scope City 21
Scopetronix 107
Shutan Camera & Video 21
Sirius Observatories 106
Star Hill Inn 108
Starsplitter Telescopes 106
Stellar Technologies 109
Stellarvue 105
Surplus Shed 106
T & T Binocular Mounts & Beyond LLC 109
Taurus Technologies 74
Tech 2000 109
Technical Innovations 37
The Telescope Store 19
Tri Scope, LLC. 106
Universal Astronomics 109
Willmann-Bell, Inc 108
Website Directory 115
Woodland Hills Photo Images 79
www.bigbinoculars.com 105
Zerpec Inc. 108

# Reader gallery

## Readers share their images . . .

Leonid over Nova Scotia /// Montana Leonid /// Leonid with star trails /// Leonid, Moon, and fog /// Fireball through clouds /// Leonid composite



*Above,* **LEONID STREAK OVER CANADA** [35mm lens at f/2, Fuji Superia 400 film, 30-second exposure] /// **BARRY BURGESS**

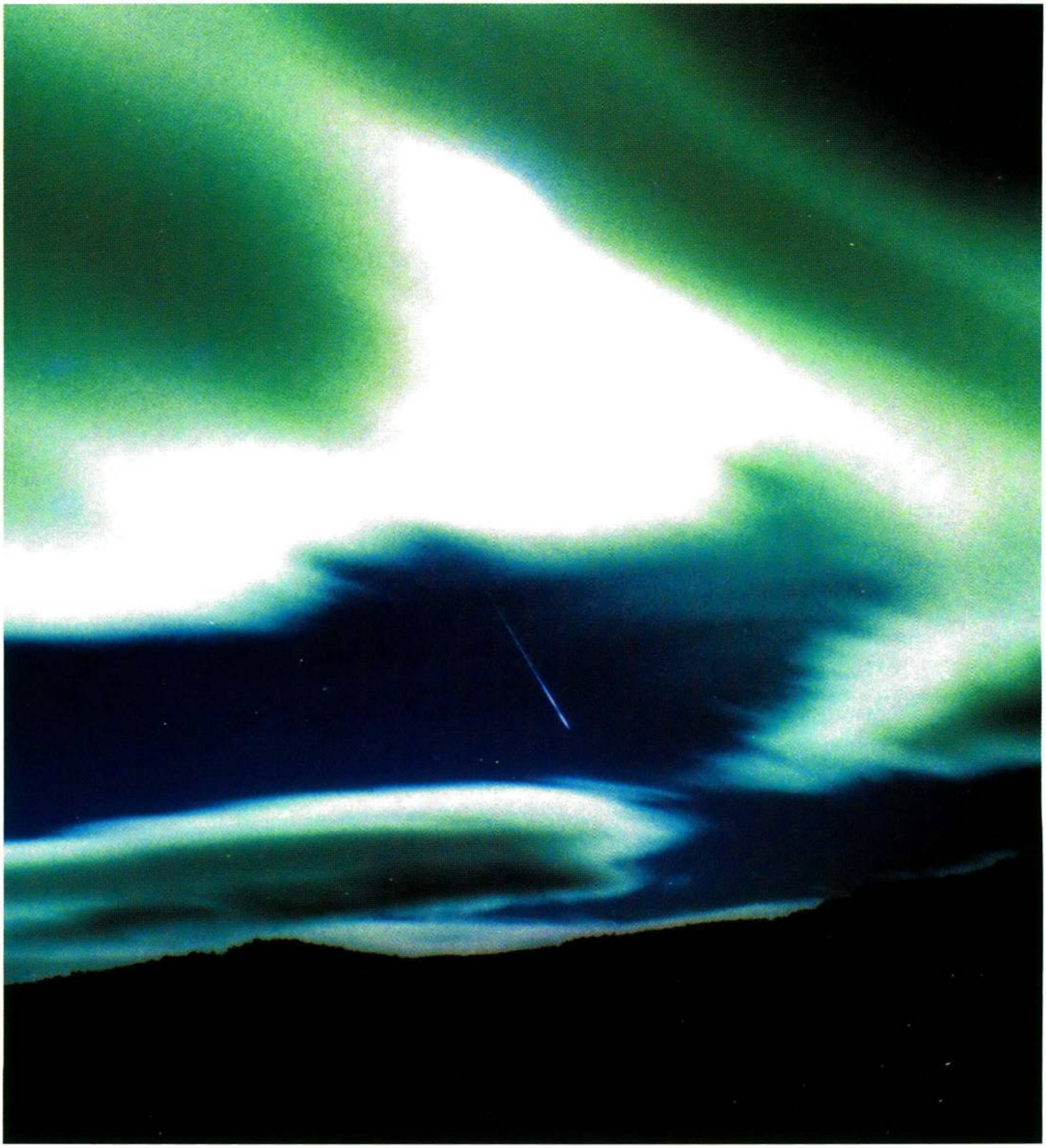
**LEONID METEOR SHOWER**

### Leonid over Nova Scotia

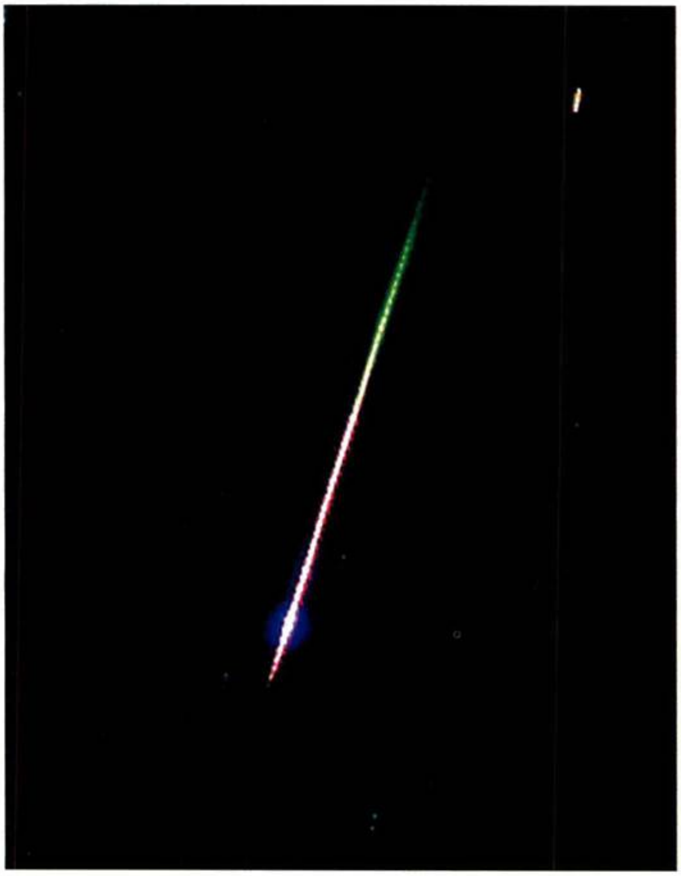
Barry Burgess caught this bright Leonid meteor on film as it soared over St. Croix, Nova Scotia, Canada, at 6:15 A.M. on November 19, 2002.

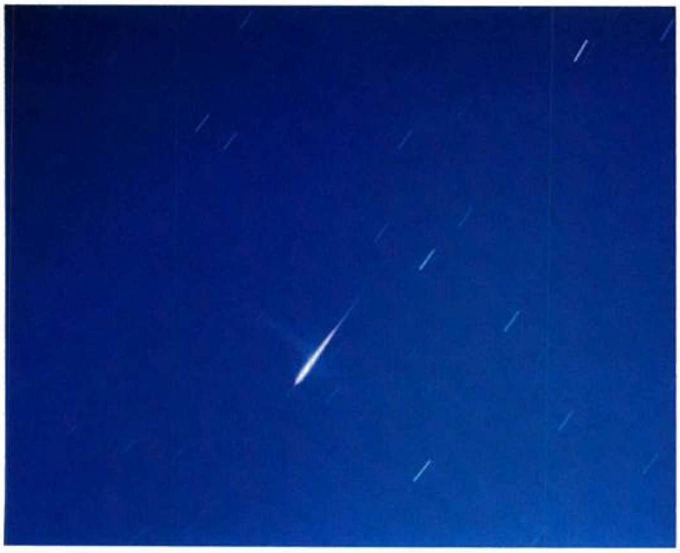
Despite the glow of a Full Moon and cloudy conditions in various locations, many observers of the 2002 Leonid shower saw 300 to 400 meteors per hour during the peak, which occurred between 5:30 and 5:45 A.M. EST. Such a Leonid show will not take place again until at least 2033, and a major storm is not likely until 2098.

Send your photos to: ASTRONOMY reader gallery, P.O. Box 1612, Waukesha, WI 53187; e-mail to readergallery@astronomy.com.
Please include your full name, date and location of image, and complete photo data: telescope, camera, film, and exposure information.



**MONTANA LEONID** [28mm lens at f/2.8, Kodak Max 400 film, 10-second exposure taken on November 19, 2002, near Silver Bow, Montana] /// **KATHIE PASCUAL**

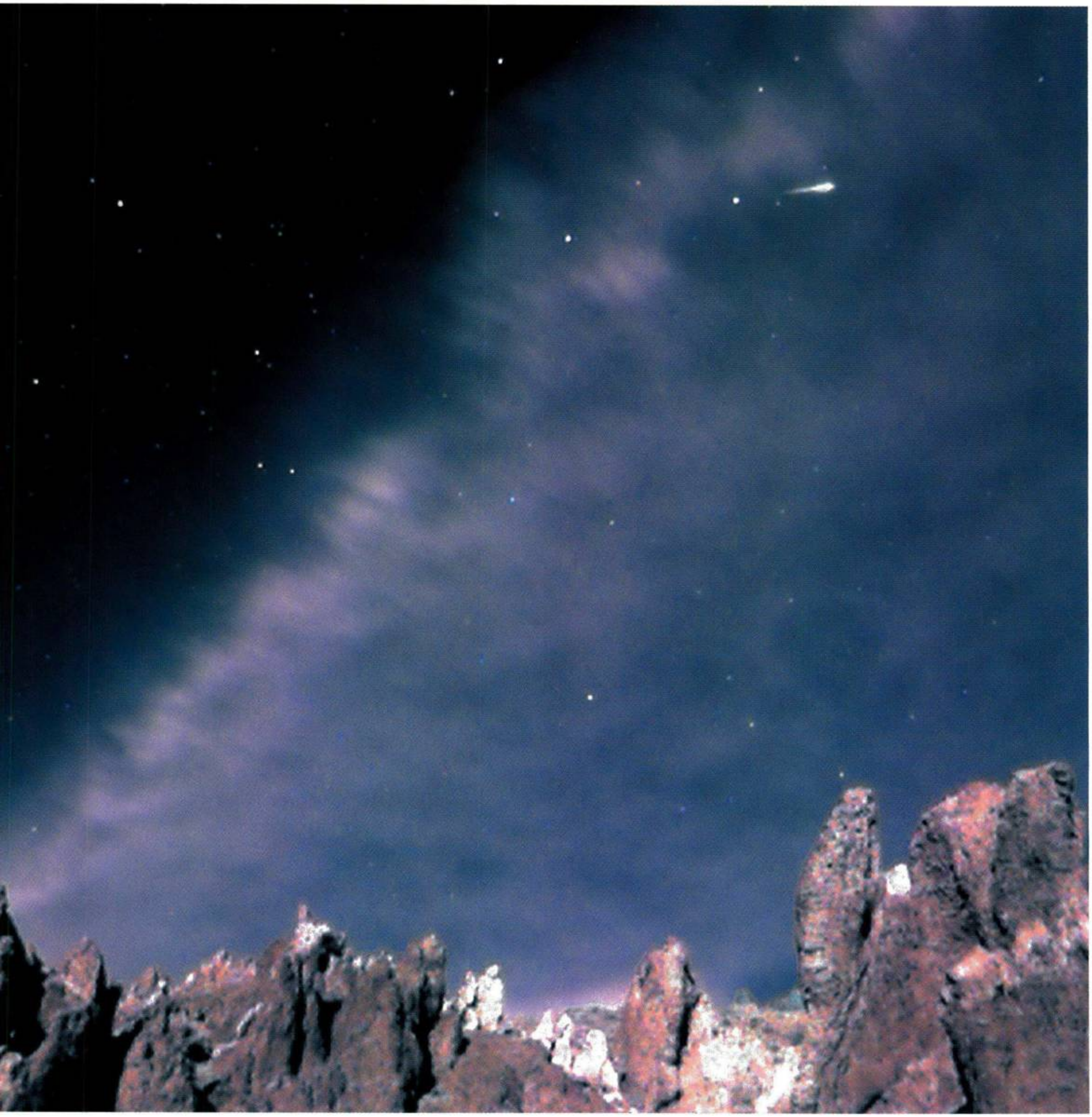




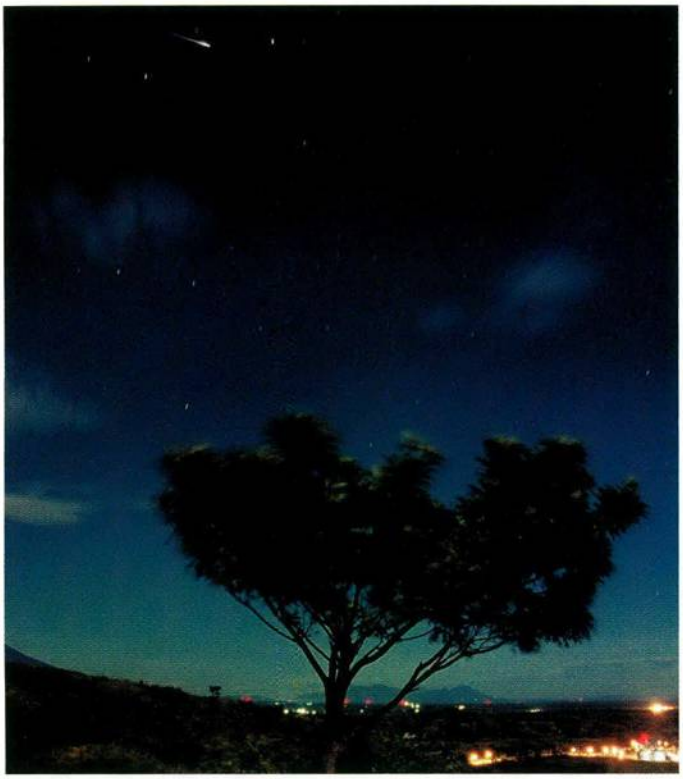
*Top left,* **LEONID STREAK** over Florida (28mm lens at f/3.5, Fuji S2 Pro 400 film, 41-second exposure taken on November 19, 2002, near Apopka, Florida) /// **BARRY VAUGHT**

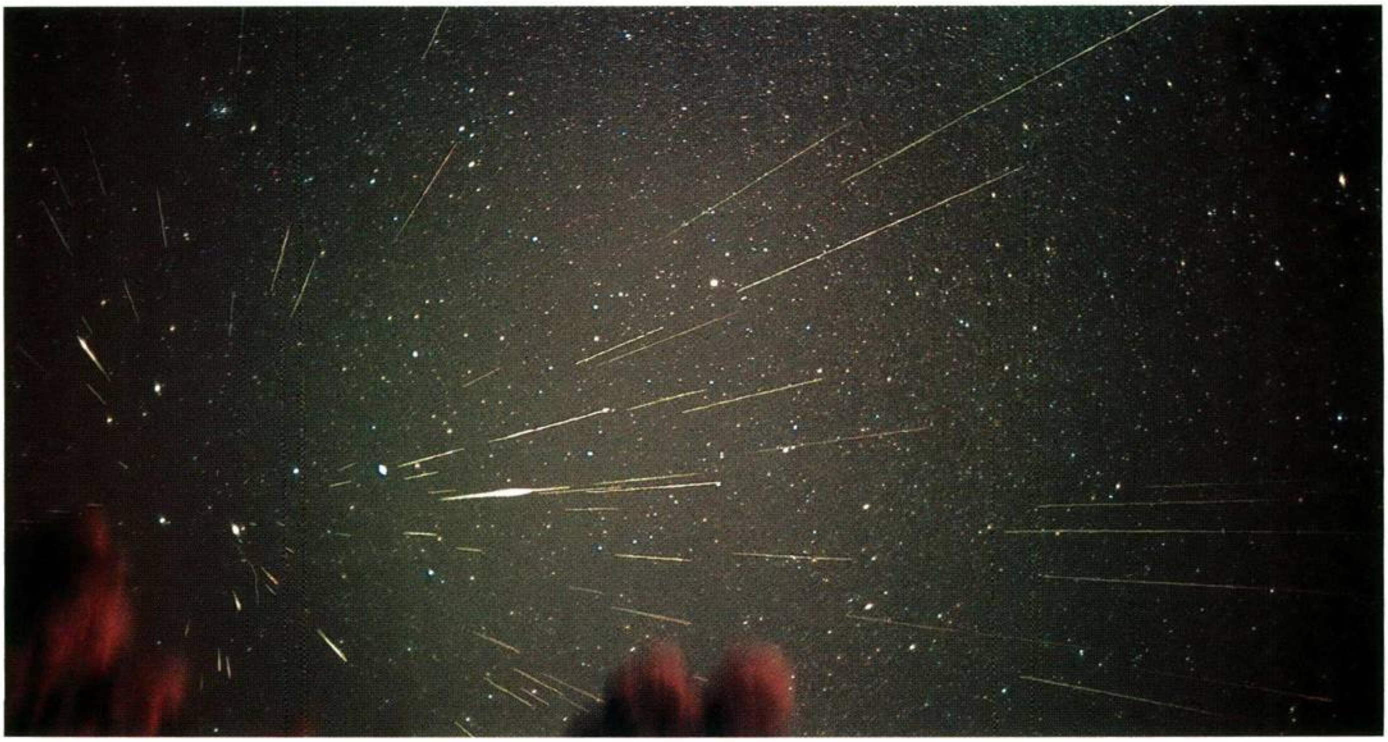
*Bottom left,* **LEONID WITH STAR TRAILS** over France (28mm lens at f/2.8, Kodak Royal Supra 400 film, taken on November 19, 2002, in L' Escaréne, France) /// **MICHEL BENVENUTO**

*Above,* **LEONID, MOON, AND FOG** over Lake Greenwood (Olympus C-3040Z digital camera at f/2.8, 10-second exposure taken on November 19, 2002, in Greenwood, South Carolina)
/// **BLAKE SUDDETH**



*Above,* **FIREBALL THROUGH CLOUDS** [Starlight Xpress MX7-C CCD camera at f/4, 20-second exposure taken on November 19, 2002, in the Canary Islands, Spain] /// **BERND PRÖSCHOLD**



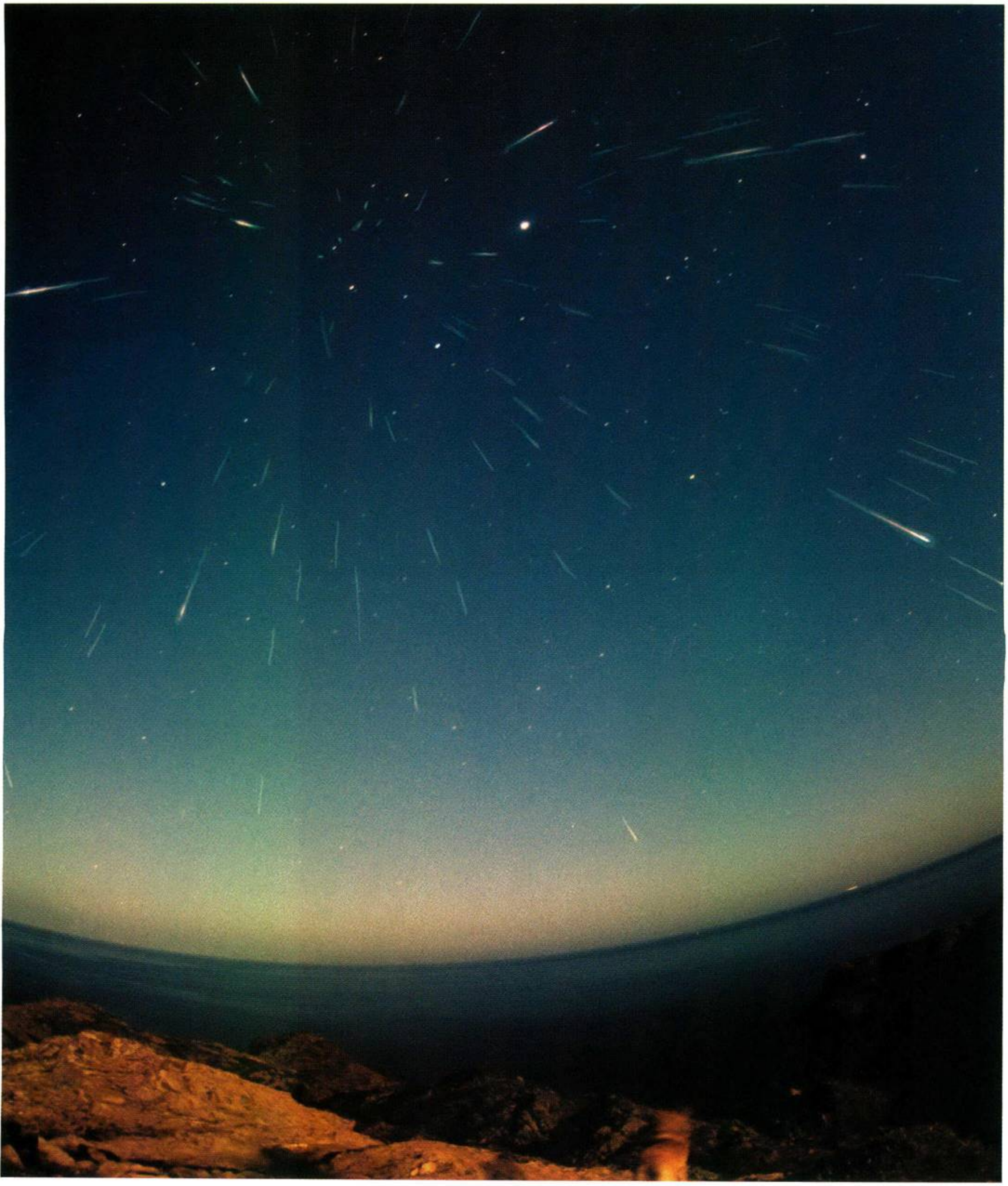


*Top left.* **METEOR OVER EL SALVADOR** [35mm lens at f/3.5, Fuji 400 film, 3-minute exposure taken on November 19, 2002, in San Salvador, El Salvador] /// **FERNANDO GOLSCHER**

*Top right.* **TWO LEONID METEORS** [20mm lens at f/2.8, Kodak Ultra 8000 film, 3-minute exposure taken on November 19, 2002, in L' Escaréne, France] /// **ANTOINE GERHARDT**

*Above.* **LEONID COMPOSITE** [20mm lens at f/1.8, composite of five 10-minute exposures, taken on November 19, 2002, in Australia] /// **RUSSO MASSIMO**

*Below,* **FISHEYE LEONID COMPOSITE** (16mm fisheye lens at f/2.8, Fuji 400 film, composite of 30 one-minute exposures, taken on November 19, 2002, in Cape Creus, Spain) /// **JUAN CARLOS CASADO AND ISABEL GRABOLEDA**



*Astronomy* (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Post Publication Agreement Number 40010760.

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Alternately, for the beginning-to-intermediate observer, the ETX-70AT is supplied with #494 Autostar Controller and #882 Field Tripod:

| | |
|---|---|
| **ETX-70AT Astro Telescope** | **299** |

Packing & shipping (ETX, Autostar, & Tripod): ETX-90EC — $30; ETX-105EC — $35; ETX-125EC — $40; ETX-70AT — $20.

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